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1899

University of the State of New York

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CONTENTS

REPORT

To His Excellency

Frank S. Black *Governor of the State of New York*

Sir: The operations of this department during the past year have been in continuation of the work of previous seasons along the following lines: *a*) the exploitation of the economic products of the state and *b*) the perfecting of the geologic map of the state. It seemed important that at the opening of the field season immediate attention should be directed to the mode of occurrence and storage of natural gas and the possibility of the development of this natural product. The striking of rich supplies of gas in the vicinity of Rome, Syracuse, at Baldwinsville and in Oswego co., in addition to constantly increasing operations in the more western and southwestern parts of the state, rendered it imperative that measures be taken at once to accumulate and conserve the important data that these numerous deep wells were affording. The work previously undertaken in this direction has been incomplete and, though important in having put on record the logs of many wells, giving the succession and thickness of geologic strata, has been altogether insufficient to establish any explanation, or to formulate a law of the mode of storage of natural gas and the method of location of paying wells. Such investigations will not be undertaken by private individuals for the reason that, though their results may be of profound ultimate effect upon the development of the mineral wealth of the state it may not be possible to convert them at once and without delay into dollars and cents. Hence all states of advanced ideas, where such accumulations of natural gas, petroleum and other mineral products are known to exist, have made it their urgent business through their official scientific departments to make known to the interested public where and under

what circumstances such natural supplies can be most advantageously exploited, and have given substantial reasons for such determinations. To carry on such work in this state a small appropriation was asked of the last legislature and granted by it, but was vetoed by the governor on the ground that such operations should be conducted by private individuals, which, as above remarked, is manifestly impracticable. With full realization of this impracticability, the work was inaugurated with such appropriations as this department had and in order to carry it on, a necessary curtailment of expenses has been made in other directions.

I have the honor therefore to present herewith the very valuable report on this subject by Prof. Edward Orton, the state geologist of Ohio, who has for years made this a subject of special study and is recognized as the foremost authority upon it in this as well as in other countries.[a]

To enable Prof. Orton to cover the entire gas field of the state in one season he was given the assistance of Prof. Irving P. Bishop, of Buffalo, who has taken special charge of the gas and oil fields of western and southwestern New York and has submitted an interesting and important report upon the result of his investigations.

In my report for 1895, Prof. Charles S. Prosser, of Union college, gave the results of his study of the Hamilton and Chemung formations in central New York. This report was but a preliminary statement of his results and the present report contains the outcome of his continued study of the distribution of the same formations in the more easterly portion of the state. This work of Prof. Prosser is of high value as it affords data for an entirely new line of division between the formations, which has for years been a matter of great obscurity on account of the homogeneity of these sediments and the slight variation of the characters of the fossils which they contain.

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[a] In order to secure for Prof. Orton's important paper a more general circulation than it could obtain through the medium of this report, it has been deemed best to issue it separately as a bulletin of the state museum. Therefore it does not appear in this report but will be found incorporated with the museum report for the current year [1899] and as Museum bulletin 30.

September, 1899.

JOHN M. CLARKE

During the past season Professors James F. Kemp, of Columbia university, C. H. Smyth jr, of Hamilton college, and H. P. Cushing, of Adelbert college, Cleveland, O., have continued their operations in the Adirondack region of crystalline rocks and the first two gentlemen present herewith reports of their work, the former in Essex co. and the latter in the western part of the Adirondack region. Prof. Cushing's results will be incorporated in a future report.

Dr Heinrich Ries, of Columbia university, has been employed to make a special study of the limestones of the state with reference to their various economic values, and his report is herewith submitted.

Mr Clifton J. Sarle, of Rochester, was sent into the field for the purpose of collecting specimens of fossil sponges to be used in the completion of the monograph of the *Dictyospongidae*, the final part of which was transmitted with my last report. Mr Sarle succeeded in securing a large amount of material in Steuben co. and visited the southern parts of Tioga and Broome counties for rare species of these organisms and from there was detailed for a short time to trace the outcrops of the upper layers of the Niagara formation in the vicinity of Rochester. Thereafter he was sent into Clinton co. for the collection of fossils in the Chazy and Calciferous limestones, in which work he was engaged for about one month. Later in the season he was engaged in the Chemung rocks near Avoca, in the collection of the crinoids of that formation, in this case with satisfactory results.

This report also contains a paper of much interest which has been communicated by Prof. Charles S. Prosser, of Union college with Mr R. B. Rowe, one of his special students in geology. It is entitled: the Stratigraphic geology of the eastern Helderbergs.

Very respectfully

James Hall

State geologist and paleontologist

State Hall, Albany, Mar. 24, 1898

REPORT

ON

PETROLEUM AND NATURAL GAS IN WESTERN NEW YORK

By Irving P. Bishop

PETROLEUM AND NATURAL GAS IN WESTERN NEW YORK

Prof. James Hall

SIR: I submit herewith my report giving the results of studies made during the summer of 1897 on the distribution and geology of natural gas and petroleum in the counties of Cayuga, Wayne, Seneca, Ontario, Monroe, Livingston, Orleans, Genesee, Wyoming, Niagara, Erie and Cattaraugus in the state of New York.

Very respectfully

IRVING P. BISHOP

SCOPE OF THE WORK

The original purpose of this investigation was to ascertain the geology and distribution of natural gas along the outcrops of the Corniferous limestone and the Hamilton group, from Onondaga co. westward.

The gradual accumulation of data from localities outside the proposed field, necessitated an enlargement of the scope of inquiry so as to include all of western New York exclusive of the southern tier of counties. Later on the work was extended so as to cover Cattaraugus co. and to embrace the geology and distribution of petroleum within its limits.

Wells in Cayuga county

Weedsport

Only two wells are reported from this co. The first of these was bored at Weedsport previous to 1873. The total depth is said to have been from 600 to 800 feet.[a] No gas of any importance was found.

Auburn

In the latter part of 1897 a well was sunk at Auburn, N. Y., starting on the lower part of the Corniferous limestone. The following record is furnished by Mr L. B. Cary, driller, and by Mr J. W. Stearns, contractor.

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a See Report of sup't N. Y. salt reservation. 1873.

Record of Auburn well

Salt water	at 635 feet	Struck gas	at 1580 feet
Cased off	645	White Medina sand	1600
Soft shale to	1025	Red Medina sand	1740
Niagara limestone	1025	White Oswego sand	2550
Black shale	1100	Black shale	2880
Blue shale	1310	Trenton rock	3300
Clinton limestone	1520	Stopped drilling	3600
Red Medina sand	1538		

Gas was found in the red Medina sandstone at 1580 feet. It is now confined in the well and has not yet been utilized. Mr Cary estimates the production at 40,000 cubic feet a day.

In the deep well at Ithaca, Tompkins co., a small amount of gas was found in the top of the Hamilton and the bottom of the Genesee.

A small streak of sulfureted hydrogen also occurred in the Lower Helderberg. The total production was too small to be of value.

Wells in Seneca county

Seneca Falls

Since 1885, 12 wells have been sunk at Seneca Falls, N. Y., to depths ranging from 1500 to 3560 feet. The following careful record of well no. 12 was furnished by Mr W. A. Hoseley.

Drive pipe to limestone	77 feet	Gray shale mixed with black	at 2360 feet
Top of salt sand	at 305	Half black shale	2400
Bottom of salt sand	455	All black shale	2440
Top of big red shale	485	Shale and lime mixed	2450
Bottom of big red shale	675	All shale	2650
Cased to	513	Top Trenton	3000
Top Niagara	710	Black shale	3200
Top Clinton	1085	Limestone	3225
Top Medina	1205	Nearly all black shale	3240
Flow of gas, enough to light	1254	Crystalline limestone	3275
Gray Medina (?)	2030	All black shale	3400
Red Medina	2140	Limestone with white streaks	3485
All gray	2175	To bottom	3560

This well produces about 5000 cubic feet of gas a day with a confined rock pressure of 500 pounds. The best gas was found about 500 feet below the top of the Trenton limestone.

Well no. 3 found a vein of gas in the Clinton which furnished, at the start, from 20,000 to 25,000 cubic feet a day. When opened, the well gives a very free flow of gas which decreases after a few days. With the gas confined, the pressure gradually rises for 24 hours to a maximum of 500 pounds, after which the gas can be again turned on to the line. In this respect the well behaves like the famous Kelly well at Zoar near Gowanda, N. Y.

The other wells strike the Medina sandstone at about 1400 feet. The upper strata are very hard with less shale than is found in the western New York field and with no indication of the white or quartzose sandstone which is there the principal gas producing rock. The specimens of sandstone brought up by the sand-pump from the gas rock at Seneca Falls, and also at West Bloomfield and Caledonia, were invariably red and generally extremely hard. The gas horizon in these wells is by no means constant. In one well it was found at 1360 and in another at 1400 feet; but in most cases it lay from 150 to 200 feet below the top of the Medina. Small quantities of gas also occurred in the same formation at lower levels.

In this group the earlier wells are now yielding better than those drilled recently.

The gas from these wells is piped to Seneca Falls where it is used for heating purposes. The company which distributes it has about 50 meters set and supplies an average of 50,000 cubic feet a day.

Wells in Schuyler county

Watkins

Information regarding the deeper borings for salt at Watkins was refused by the owners of the wells.

Near the sanitarium at Watkins a well was sunk about 20 years ago to the depth of 1530 feet.[a] There is no record or even tradition that gas was found in any quantity. When the well was completed it was plugged at two or three points and abandoned. A few years ago the upper part of the well was cleaned

[a] It is reported that the drill stopped in black shale.

out and at once filled within 300 feet of the top with mineral water, which has since been utilized at the sanitarium for baths. In June 1897, just after the slight earthquake shock which was felt in western New York, the engineer noticed that the odor of gas was increasing at the mouth of the well.

A meter was attached and registered a flow of 3000 cubic feet a day. The well was then pumped to 850 feet when the pressure rose to 100 pounds and the flow increased to 10,000 cubic feet a day. In August 1897 the well was supplying fuel for the pumping engine and for the large range in the sanitarium kitchen.

Though the increased flow of gas mentioned above may have been caused by seismic disturbance, it is more probable that it was due to diminished water pressure in the well caused by excessive pumping.

Wells in Ontario county

Geneva

At Geneva a well was bored in December 1885 to the depth of 1100 feet. No gas was found, but a copious flow of mineral water now fills the well and supplies the baths of the sanitarium. No record of this well has been preserved.

West Bloomfield

The first well in western New York to produce gas in paying quantities was sunk, according to Prof. Charles S. Prosser, in West Bloomfield township about 1863-64.[a]

This is reported to have given in a still atmosphere, a 30 foot flame from a five inch pipe with an estimated daily production of 400,000 cubic feet. A line of wooden pump logs was laid from the well to Rochester and connected to the gasometer of the local gas company with the intention of supplying both fuel and lighting. Water and mud entering through loose joints between the logs effectually closed the line after a few days and it was abandoned. Prof. Lattimore, of Rochester, informs me that, while it lasted, the gas was used for fuel in at least one of the hotels.

[a] See C. E. Ashburner Petroleum and natural gas in New York 1888. p. 42. Also American journal science and arts (2) 49:336–37.

Another well was sunk on the Lee farm one quarter mile north of Gates's mills about 1871; and in 1883 active drilling was resumed in that vicinity and continued with slight interruptions up to 1896. At present there are 40 wells in this field, the greater number of which range from 450 to 550 feet in depth and find their gas in the lower part of the Marcellus shale. In 1894–95 two deep wells were sunk to the Medina sandstone in the vicinity of Gates's mills with the hope of increasing the supply of gas from a lower horizon. One of these proved barren; the other gave a flow of about 100,000 cubic feet daily at a depth of 2100 feet. The gage broke at 600 lb., the limit of registration, so that the full rock pressure was not ascertained.

Of the shallow wells, one gave at the start 100,000 cubic feet of gas a day with a maximum confined rock pressure of 30 pounds which later fell to 18 pounds; 10 or 12 wells gave 40,000 cubic feet or better, and the others 20,000 or less with a pressure ranging from 30 to 18 pounds.

The gas is now piped to the villages of North and West Bloomfield and to Honeoye Falls.

The Ontario improvement and gas co., limited, owns the plant and supplies 200 stoves during the year, but not all at one time. At present the wells furnish barely enough gas to meet the demands of consumers. In January 1898 a new well was drilled, but failed to increase the supply materially.

The records of nearly all the borings in this field have been placed at my disposal by Mr S. Miner Wellman of Friendship, N. Y. and by Mr Isaac E. Dean, who drilled many of the wells.

The following show the characteristic conditions observed here.

Record of deep well s. e. corner of lot 54, two miles north of Allen Hill, in West Bloomfield township

Pocket of gas at	431 feet	Bottom of Niagara (?) at	1770 feet
Hard rock (Corniferous?)	450	First show red rock	1815
Through hard rock	590	Top of Medina sandstone (?)	1860
Onondaga (?)	960	First gas	1945
Salt mixture	1193	Gas, main flow	1955
Clear salt (9 ft)	1218	Bottom of well	2042
Cased to	1307		
Small streak of salt	1510		

The interrogation marks are my own; the other records are those of the driller. The red rock at 1815 feet is probably the top of the Medina.

Second deep well, near the first

Shale gas	at 380 and 457 feet	Red rock	1300 feet
Gas producing 30,000 cu. ft a day	490	Cased	to 1317
		Top of shell	1840
Hard rock gas	805	Gas	1948

The gas at 805 feet was very abundant in both wells but did not last.

Worthington well, no. 1

Located on high ground one mile north of Allen Hill. Record from Mr I. E. Dean

Drive pipe	98 feet	Light gas	415 to 430 feet
First gas	168	Best gas	472 to 484
Cased to	200	A little gas	476
Light gas	at 335	Black rock (Marcellus)	519
Light gas (shot)	357 to 367	Bottom of well	525

Worthington well, no. 2, lot 45

Bed rock	at 32 feet	Water	at 170 feet
Limestone to	36	Chocolate slate	185
Large vein water	95	Gas 400 to	410
Cased in chocolate rock to	105	Shells	424
Dark chocolate slate	124	Finished	447
Slate	140	Shot 400 to 447 feet	

Worthington well, no. 3, lot 46

Bed rock	at 31 feet	Cased	at 201 feet
Chocolate shale	110	Good gas	378
Cased at 135 and	170	Light gas	418
Hard shell	190	Bottom of well	453

H. Arnold well, s. w. cor. lot of the township

Bed rock	at 80 feet	Gas	at 290 feet
Slate through first chocolate	156	Shell	412
		Shot	430
Limestone (?)	171	Gas at 800, 812 and	860
Water	172	Gas increased to	890
Cased to	183	When the flow was very large.	

This well gave 120,000 cubic feet and was the best shallow well in the field.

Pierpont well, lot 35, south of Allen Hill

Drilled April-June 1889

Bed rock	at 6 feet	Lighter chocolate shale	at 370 feet
Iron pyrites	107	Light gas	380
Light colored shale	115	Good show of gas	394
Chocolate colored shale	150	White lime shell	400
Big vein water	200	Dark chocolate shale	412
Cased to	205	Water	574
First gas	209	Shells full of gas 628, 633 and	660
Lime shells	224	Black (Marcellus) shale	680
Lime shells	260	Limestone (Corniferous)	733
Chocolate shale	318	Finished	782
Gas	328		

Thompson well, no. 2, lot 54, West Bloomfield

Bed rock	at 53 feet	Third gas	at 315 feet
Cased to	71	Finished, top of Corniferous	414
First gas	104		
Second gas	140		

Lee well, no. 1, one fourth mile north of Gates's Mill

First well drilled about 1871. Record from Mr I. E. Dean

Bed rock	at 10 feet	Second gas	330 to 365 feet
Cased	97	Finished	at 418
First gas	at 230		

This well was a good producer and did not reach the Corniferous limestone.

Lee well, no. 7

Drive pipe	60 feet	Second gas	188
Casing	140	Completed at Corniferous	460
First gas	at 123		

Well barren.

Rollins well, no. 2, lot 6, West Bloomfield

Located on a hillside

Drift	194 feet	Total depth	495
Small show of gas	415		

Well barren.

Rollins well, no. 3

To rock	27 feet	Limestone	420
First gas	295 to 310	Second shot	455
First shot	at 300	Finished	at 475 feet

Rollins well, no. 6

Cased to	99 feet	Fourth gas	330
First gas	at 140	Finished, above Corniferous	438
Second gas	268		
Third gas	300		

Fair.

McAllister well, no. 2

Bed rock	at 75 feet	Third gas (shot)	430
First gas	165	Fourth gas	475
Second gas	210	Finished at Corniferous	504

McAllister well, no. 4

To rock	36 feet	Gas 730 to 746 and also	780
First gas	431 to 441	Salt water	784
Limestone (Corniferous?)	at 455	Gas, strong	at 820 feet
Gas at 484, 505, 545 and	576	Gas, increased	835
Good gas	696	Fresh water at bottom of well	855

McAllister well, no. 12

Bed rock	at 36 feet	Center of shot	at 428 feet
First gas	431	Finished at Corniferous	441

Well barren.

Emerson well, no. 5, McAllister farm, Gates's Mill

Record from Mr I. E. Dean

Drift	48 feet	Chocolate shale, with a little gas	at 415 feet
First gas	at 137	Black shale	415 to 452
Second gas	345	Corniferous limestone	at 452
Gas from	370 to 381		
Black shale	at 410		

Case well, no. 2

Bed rock	at 12 feet	Corniferous	at 448 feet
First gas	385	Drilled into limestone	4
Second gas	428		
Third gas	448	Total	452

Well shot at 385 feet increasing the flow of gas. A second shot at 425 feet was unsuccessful. This was one of the best of the shallow wells.

Case well, no. 3, one mile north of Allen Hill

Record from Mr I. E. Dean

Bed rock	at 77 feet	Finished above Corniferous	at 517 feet
Gas and water, 90, 148, 171, 183, 212, 247 and	333		

Well torpedoed with 15 foot shot between 457 and 475 feet. The top shot at 457 feet was unsuccessful. The lower shot produced a good flow of gas.

Johnson well, Richmond township, one mile n. e. of Allen Hill

Record from Mr I. E. Dean

Bed rock	at 28 feet	Fourth gas	at 512 feet
Red shale	175	Shells	527
Cased	228	Fifth gas	532
First flow (pocket)	229	Shells	537
Second gas	360	Sixth gas	538
Best gas	492		

First shot 492-507 feet.

Second shot 523-538 feet.

Morrow well, no. 1

Bed rock	at 26 feet	Shell	at 190 feet
Chocolate rock	130	Gas, good	381
First gas	130	Gas (shell)	403
Second gas	146	Gas, good	430
Slate	180	Bottom of well	468

Shot at 430 feet.

Norgate well, lot 51 (Richmond?) near center of township

Bed rock	at 17 feet	Slate	at 398 feet
First gas	30	Shell	670
Black rock	30	Gas	681
Chocolate rock	78	Black rock	706
Shell and more gas	80	Shell	726
Light slate	120	Limestone	736
Chocolate	340	Finished	741
Cased to	342	Shot	660-675

The principal gas horizon of the shallow wells is in the lower part of the Marcellus shale, and near the Stafford limestone. While in a number of cases gas has been found above the Stafford horizon, the weight of evidence goes to show that the gas originates in the densely bituminous black shales at the base of the Marcellus and is held in by the limestone which serves either as a cap where it is continuous, or as a reservoir where it contains loose joints and fissures. The pocket of gas at 805 feet in the deep wells appears to be too deep to lie in the honeycombed "bullhead" waterlime at the top of the Salina group, and is probably a small inconstant horizon. There is nothing in either the records or in the drillings preserved to show that the white or "quartzose" Medina sandstone exists here. The gas rock in the Medina, as shown by the drillings, is a nearly pure, compact red sandstone having the usual characteristics of the Medina of western New York.

Vincent

At Vincent in the town of Bristol a well sunk in 1865 furnished a small amount of gas which apparently came from the Marcellus. The borings at Canandaigua, Clifton Springs, Naples and elsewhere in Ontario co. have produced no gas of any importance.

From the Canandaigua lake region C. A. Ashburner reports petroleum in several wells, one of which is said to have produced five barrels a day. This report I have not been able to verify.

Wells in Livingston county

Avon

The following record of a well at Avon in the northern part of Livinston co. is furnished by the driller, Mr Frank Westcott.

Top of Corniferous	at 170 feet	Gas	at 1463 feet
Top of Niagara	875	Depth of well	1525
Top of Medina sandstone	1400		

The maximum closed pressure is reported to be 500 lb. The daily production was not ascertained.

Caledonia

At Caledonia six wells have been drilled by Mr. J. C. Tennent and another is now (Jan. 1, 1898) under way. No record of these was kept until the Medina sandstone was reached. Mr Tennent has furnished me with the following facts regarding the best well.

Elevation of well mouth A. T.	560 feet	Top of Medina sandstone	at 997 feet
Drive pipe to (Corniferous limestone)	78	First show of gas	1010
Casing to shut off salt water	472	Second show of gas	1069
		Pay gas	1085
		Through gas sand	1098
Red shale	at 987	Depth of well	1119

Stopped in red shale.

Well finished Nov. 12, 1895.

The confined gas pressure was 400 pounds with a flow of approximately 150,000 cubic feet a day.

The other wells showed no marked difference in the nature or thickness of strata except that in three the sandstone was but 75 feet thick, the lower sand being replaced by red shale. As the lower part of the sandstone is the gas horizon, these wells were nearly barren.

The other producing wells yielded at the start approximately 3000 cubic feet a day with an initial pressure of about 175 pounds.

The gas from these wells supplies 65 connections in the village of Caledonia. Among them are the village water-works and several large establishments using power.

Batavia

Record from Prof. Charles S. Prosser

Altitude 889′ A. T.

Depth	Thickness	
	40′	Drift
40′		
	60′	Marcellus
100′		

Depth	Thickness	
	150′	Upper Helderberg, Lower Helderberg
250′	——	
	500′	About 15′ rock salt at 600′ — Onondaga Salt group
750′	——	? Top of Niagara limestone
	500′	Niagara
1000′	——	Clinton (?)
	100′	Probably mostly Medina
1100′	——	Medina
	900′	Bottom of well in Medina
2000′	——	

Of the 150′ assigned to the Helderberg formations it is probable that, as in other known sections in western New York, 100 feet should be considered Corniferous and the lower 50 feet of water-lime should be classed as the upper part of the Onondaga group. The Clinton, which Prof. Prosser doubtfully assigns to the 1000′ horizon could hardly have been represented among the samples from which the record was compiled. In the Corfu well, which agrees in its general features with others in western New York, the Niagara limestone is reported to be 250 feet thick with 70 feet of shales below. The Clinton limestone is 30 feet thick with a thin underlying band of olive shales, the latter averaging about five feet. As no sample was taken between 1000′ and 1100′, the Clinton was probably overlooked.

Wells in Genesee county

Le Roy

Mr. J. C. Tennant has drilled a well on the Monroe farm, one mile east of the village of Le Roy, Genesee co. The elevation of this well above tide is 690 feet. The Medina sandstone was found at 1025 feet and proved to be 75 feet thick. A small showing of gas was found in the upper part of the sandstone, but was not enough to be of any use. The well was completed in red shale at 1200 feet.

In the original well bored for salt at Le Roy, February 1879, a small pocket of gas was found at 450 feet. None of the wells since drilled in that vicinity have found any gas worthy of record.

Corfu

At Corfu, in Genesee co., five wells have been drilled, four of which are nearly in a north and south line at an average distance of 1000 feet apart. In two of these the original confined rock pressure was 400 pounds, and in another, well no. 4, the gage showed 500 pounds pressure after one night. Well no. 5, completed during the autumn of 1897, is reported by Mr J. W. Stearns, the contractor, to yield 250,000 cubic feet a day. This last well is located near the Lehigh railroad tracks at the extreme southerly end of the group, and is the best well yet put down.

The gas is piped through the village of Corfu, and in August 1897 supplied 108 connections. Water in two wells has caused decreased pressure, but there appears to remain a supply ample for the needs of the village for years to come.

The geological conditions occurring here are shown by the following record furnished by Mr J. W. Stearns.[a]

Well no. 1, Corfu

Marcellus shale	30 feet	Niagara shales	70 feet
Flint (Corniferous)	180	Clinton	30
Limestone and shale	458	Medina sandstone	110
Niagara	250	Red shale	20

Wells in Wyoming county.

Attica

The first deep boring in this vicinity was an exploration for salt in the later part of the year 1883.[b] Not finding salt in paying quantities, the well was continued down to 1960 feet, about 240 feet below the top of the Medina group, without getting any show of gas. In September 1897 a well was sunk for Hon. F. C. Stevens about 400 feet west of the original boring. The well is

a See Report N. Y. state geologist. 1898.
b See author's paper in report N. Y. state geologist 1885.

located near the edge of a deep preglacial valley now filled with drift, the mouth being approximately 990 feet above tide. The following record was furnished me by the contractor, J. W. Stearns.

Stevens well, no. 1

Completed Sep. 14, 1897

Drift	204 feet	Niagara limestone	at 1475 feet
Shale (Genesee (?) and Hamilton)	to 550	Black slate	1570
Corniferous limestone 160 ft	to 710	Clinton	1605
Limestone and shale mixed	to 1050	Medina sandstone	1704
Black and red shale	1250	Red shale to bottom of well	4
		Total depth	1708

First gas	at 1658 feet	Third gas	at 1690 feet
Second gas	1672		

Mr Stearns reports the original confined rock pressure as 650 pounds with an estimated (but not measured) capacity of 400,000 cubic feet a day. The gas from this well is now piped through the mains formerly used for illuminating gas and supplies about 100 connections. At the time of my visit, Jan. 8, 1898 the gage registered 220 pounds at 4 p. m., an hour which would represent a fair average of use between sunrise and sunset. The superintendent in charge said that the pressure rose during the night to 480 pounds.

Three other wells have since been sunk, two of which belong to Mr Stevens and the third to Mr Benedict. Stevens well no. 3 on the Flach farm west of the village has, according to Mr Stevens a confined rock pressure of 620 pounds. The well has not been metered, but is roughly estimated at 200,000 to 250,000 feet a day.

It is reported that Stevens well no. 1 passed through about seven feet of rock salt.

In the numerous borings for salt throughout Livingston and Wyoming counties, gas in any quantity has been generally absent. Enough gas for two stoves is reported from one of the Kerr wells at Rock Glen, Wyoming co., apparently from the Ham-

ilton shales. In the well at Dansville, Livingston co. small streaks of gas were found at 295 and 508 feet respectively.[a] In both instances the gas was found at too high an elevation to have come from the Marcellus shales, and it is therefore quite certain that this horizon is not productive of gas in the counties under consideration. As the borings for salt seldom penetrate to the top of the Niagara limestone, they are too shallow to reach the lower horizon from which gas is generally derived.

Arcade

At Arcade, in the southwestern part of Wyoming co. near the Cattaraugus co. line, four or five wells have been drilled of which no complete record has been kept. In the well located on the M. J. Stearns farm and drilled by John Smith of Ormsby Junction, Pa. the following conditions were found.

Drift	110 feet	Gas sand, 14 feet	at 730 feet
Shut off fresh water	at 290	Gas sand, 24 feet	2200
Shale	to 750	Salt water	2405

which filled the well and flowed.

The gas sand at 730 feet furnished a pocket of gas sufficient to run the boilers two days. The well was finally plugged at about 2250 feet and shot at 2200 feet with 70 quarts of nitro-glycerin, giving a fair flow of gas. Two years and four months later it gave a measured flow of 1100 feet of gas a day.

The above record was furnished from memory by a gentleman interested in putting down the well, and is probably only approximately correct.

Wells in Erie county

Very little drilling has been done in this county within the two years which have elapsed since my last report. In the latter part of 1897 and in January following, the Buffalo cement co. put down two new wells near their works on Main st. One of these gave an output of 25,000 cubic feet, and the other not more than 3000 cubic feet a day. The Buffalo natural gas fuel co. is now (February 1897) sinking a well at Ebenezer in the South Buffalo field.

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a C. S. Prosser, Thickness of Devonian and Silurian rocks of western N. Y. p. 74.

Two wells were also put down in the Canadian field near Crystal Beach about a year ago, but did not give a profitable yield. No geologic facts of importance have been brought to light by any of these borings.

At North Collins, about 17 miles southwest of Buffalo in an air-line, a well was put down during the latter part of 1897 to a depth of 1800 feet. The mouth of the well is about 100 feet below the lowest Portage sandstones and approximately 830 feet above tide. I was told that samples from every screw of drillings had been preserved, but access to them was not allowed me. Mr H. D. Auerbach, one of the company engaged in putting down the well, gave me the following data.

Shale to Corniferous limestone	1028 feet	Shales to bottom of well	at 1800 feet
Limestone	to 1240	Salt water at	1800

I visited the well Nov. 27, 1897 and obtained a sample of the drillings at 1800 feet. They were very hard limestone, effervescing slightly in cold and dissolving rapidly and almost completely in hot hydrochloric acid. From its position and characteristics I was satisfied that the rock at the bottom of the well was the top of the Niagara limestone.

At the time of my visit the well was furnishing enough gas for the boiler. In the following week the well was shot with 80 quarts of nitro glycerin at the base of the Corniferous, or more probably in the "bullhead" waterlime at the top of the Salina, securing an increased flow of gas, the quantity of which I could not ascertain. The well had not been metered Feb. 22, 1898, and the estimates obtained from different members of the company owning the well varied from 10,000 to 2,000,000 cubic feet a day.

If the above stratigraphic data are correct, they show that the limestones of the Corniferous and Upper Salina are here 60 feet and the Salina shales at least 150 feet thicker than in the northern part of the county.

Of the well at New Oregon, eight miles east of North Collins, no record has been obtained. A well is now in process of drilling on the House farm between Springville and Zoar.

NORTHERN TIER OF COUNTIES

The following records collected from various sources show the thickness of the strata in the counties bordering on Lake Ontario from Cayuga co. westward. With the exception of the Clyde well, the borings start upon the Medina outcrop or upon the northern edge of the Niagara, and all penetrate the Trenton to a greater or less extent. As will be seen, gas occurs very sparingly throughout this strip.

Wells in Wayne county

Clyde

Altitude approximately 389′ A. T.[a]

Gray, green and blue marls with gypsum	152 feet
Red marls	156
Blue and green marls (Salina?)	32
Dark blue limestone, upper div. of Niagara	110
Shaly limestone of the Niagara	225
Approximate top of Clinton group	675
Clinton group	83
Medina red shale	24 feet
Greenish, gray, siliceous sandstone, the "Gray band"	3
Red shale alternating with red sandstone forming the red Medina	915
Oswego gray sandstone of Vanuxem	92
Bottom of well	at 1792

Gas was found at 380 feet in the blue Niagara limestone and continued to about 500 feet. At 685 feet a pocket of gas was developed in the Clinton which was soon exhausted. The gas, when lighted, supports a flame three or four feet high.[b]

Wolcott

Drilled October 1887

Altitude approximately 317 ft A. T.

1 Shaly layers of Niagara limestone above and Clinton below	214 feet
2 Oolitic iron ore and shales of Clinton group	16
3 Red shale alternating with red siliceous sandstone forming the red Medina	690 feet
4 Oswego sandstone of Vanuxem	210

a C. E. Ashburner. Petroleum and natural gas in New York. 1888, p. 36.
b C. S. Prosser, American geologist. Oct. 1890, p. 203.

5 Some blue shale alternating with gray siliceous sandstone similar to the Oswego sandstone	170 feet	8 Lower part of Utica shale	590 feet
6 Undoubted Hudson river blue shale	15	9 Compact blue limestone alternating with shaly layers forming top of the Trenton	750
7 Gray sandstone containing gas, followed by dark blue shale	5		

Gas was found from 1100 feet on. The largest amount came from the sandstone at 1355 feet in the Hudson river group.

Veins were also found in the Trenton limestone at 2092 and at 2330 feet, the larger quantity at the greater depth. The well gave a metered flow of 5000 cubic feet of gas a day.

Wells in Monroe county

Rochester

Record by Prof. H. L. Fairchild[a]

Altitude 484 feet A. T.

Drift	22 feet	Trenton	954 feet
Niagara and Clinton	228	Calciferous (?)	137
Red Medina	1075	Archean	3
Oswego or Oneida	83	Bottom of well	at 3100
Hudson river and Utica	598		

No gas of consequence.

Brockport

Record by Prof. C. S. Prosser[a]

Altitude 538′ A. T.

Depth			
500	Medina red shale	Medina	
900	Darker red shale	Medina	
950	Very dark red shale	Medina	
1000	Gray and bluish chips, calcareous	Hudson river and Utica shale	About ¼ are light gray, slightly
1400	Blue shale and sandstone	Hudson river and Utica shale	
2000	Blue compact Trenton limestone to bottom of well.		

A small flow of gas at 1200 feet.

a Proc. Roch. acad. sci. 2:91.

Wells in Niagara county

Gasport

The following record is furnished me by Prof. C. S. Prosser who obtained the data from Mr C. V. Mesler of Gasport.

Niagara	Loam 8 feet to	8 feet
	Shale 6 feet to	14
	Clinton sandstone (?) 8 feet to	22
	Medina sandstone 50 feet to	72
	Marl 8 feet to	80
	Gray belt 24 feet to	104
	Medina marl or shale of the Medina epoch 716 feet to	820[a]
	Argillaceous sandstone 60 feet to	880
Hudson river	Blue alternating with red shale 280 feet to	1160 feet
	Gas at	1080
	Blue shaly limestone of the Hudson riv. epoch 340 feet to	1500
	Dark, slaty bituminous shale of the Utica epoch 300 feet to	1800
Trenton	Trenton limestone 170 feet to	1970 feet
	Chazy limestone of Trenton epoch 30 feet to bottom of well at	2000

Holly

Bored 1897-98

Record by J. W. Stearns, contractor

Red Medina sandstone and shales mixed		to 600 feet	Black shale	850	to 1420 feet
Oswego sandstone	600	to 850	Trenton limestone	1420	to 2025

when drilling was stopped.

Small flow of gas	at 1770 feet	Best gas	at 1965 feet
More gas	1827	Big pocket of gas	1975

Mr Stearns reports a confined rock pressure of about 200 pounds, and estimates the production at about 100,000 cubic feet a day.

Lockport

About two years ago a well was sunk on the farm of J. Wright McCollum in what is known as the "lower town." The mouth of the well is at about the horizon of the Clinton limestone.

At a depth of about 1150 feet a small vein of gas was found which gave a confined rock pressure of 87 pounds after 24 hours. The well was drilled to the middle of the Trenton limestone with-

[a] The upper 187 ft marked "salt."

out finding further gas and was abandoned at 2150 feet. The gas was piped to Mr McCollum's house and now supplies five stove and grate connections, and 30 gas burners. The gas is said to be of a quality fully equal to the illuminating gas furnished the city of Lockport.

Clifford Bros. are now sinking a well for gas near the canal opposite the Erie railroad station. It is intended to proceed no lower than the white Medina sandstone.

Record of well no. 2 of the Niagara oil and gas co.

Located on the Bradshaw farm near Coomer p. o., dist. 13, lot 36, township of Newfane[a]

Drilled Jan. 4, 1892

Red Medina, dark Hudson river and Utica shale	to 1200 feet
Trenton	1200 to 1910
No Potsdam	
Calciferous	1910 to 1930 feet
Hydromica and dark green schists of the Archean	1930 to 1980

The well had a little gas from 1912 to 1918 feet.

Well was cased to 243 feet and was dry afterward.

CONCLUSIONS REGARDING NATURAL GAS IN THE DISTRICT STUDIED

Careful observations extending over Erie co. and eastward as far as this investigation has gone, lead me to the following conclusions regarding natural gas:

1 It originates from the decomposition of organic matter, and accumulates in the same or an adjacent overlying stratum which acts as a reservoir.

2 This reservoir-stratum may have an impervious cap which prevents the upward movement of the gas: or it may be porous like sandstone, or contain wide joints or fissures like limestone.

3 The capacity of the reservoir depends upon the thickness of the stratum; the looseness of cohesion among the grains composing the sandstone, or the size of the joints of a limestone; or the form of structure which the reservoir takes, as for example an anticline or arch.

[a] See report of N. Y. state geologist. 1895, p. 386.

4 Where the rock dips uniformly in one direction, as it does in western New York, the gas has a tendency to escape at the northern outcrop. Consequently small quantities of surface gas may occur at the reservoir outcrops, and borings near these outcrops will find very little gas or gas at low pressure.

5 In general, deep wells show greater pressure than shallow ones; and this is, in many cases at least, independent of hydrostatic causes.

6 The gas-horizons in the district under consideration are the Trenton limestone, the Medina sandstones, the Clinton, the Niagara limestone, the waterlime beneath the Corniferous limestone, and the Marcellus at about the horizon of the Stafford limestone. Shallow wells have found an inconsiderable amount of gas among, or just below, the Portage sandstones.

7 South of the Corniferous outcrop, borings extending into and through the Trenton have not found paying gas in the latter formation. North of the Corniferous outcrop the yield in the Trenton has been better, but can not be considered as paying. These borings have been so expensive and unsatisfactory that further attempts to reach Trenton gas are not recommended.

8 The Medina sandstone is the best producing rock, and nearly all the gas is found within 200 feet of the top of that formation. In Erie co. the Quartzose sandstone of Hall, or "White Medina" as it is generally called, is the main reservoir. It is less than 150 feet below the top of the Medina and thins rapidly eastward from Erie co.

9 The presence of gas in the Quartzose sandstone appears to depend upon the softness of the rock. If anticlines in the stratum occur, they are too low to be perceived.

10 The Clinton has furnished paying gas in a few instances.

11 A small quantity of gas containing sulfureted hydrogen is often found in the upper part of the Niagara limestone. This does not pay except where used with gas from a lower level.

12 The honeycombed waterlime beneath the Corniferous often contains pockets of gas, and in the case of the Kelly well at Zoar has given the best well in Erie co. It is a promising horizon where wells are started on the Portage outcrop.

13 Borings along the Medina outcrop and the northern edge of the Niagara have been unprofitable.

14 A number of wells drilled along the northern edge of the Corniferous outcrop and in one case (at Getzville, N. Y.) on the Salina outcrop have yielded a fair amount of gas.

15 The greater part of the paying wells are located along the Marcellus and Hamilton outcrops.

OIL AND NATURAL GAS IN CATTARAUGUS CO.

Historical

The development of the petroleum industry in Cattaraugus co. began near the village of Limestone in 1864. The first well in the Tuna valley was drilled by Olmstead on the Crookes farm in Pennsylvania, about one half mile south of the state line. The discovery of a small amount of oil in this boring stimulated exploration, and in the early part of 1864 Dr James Nichols, Henry Renner and Daniel Smith sunk a well just north of Limestone village, to the depth of 570 feet. They found oil, but not in paying quantities, because as was afterwards ascertained, they did not go deep enough. Soon after, the Hall farm petroleum co. of which Job Moses was a prominent member, put down a well about three fourths of a mile west of Limestone on the opposite side of the valley. Oil was found in the third sand at a depth of 1060 feet and yielded for a few hours at the rate of 200 barrels a day. Owing to an accident, the well was ruined by an influx of water before its true value was ascertained. Moses immediately purchased 9000 acres in addition to the original tract of 1200 acres, and leased 1000 acres more.

The further development of the property appears to have languished and the operations of Moses were unprofitable. In the same year Dr Nichols and others sunk an unsuccessful well on the Bailliet farm, north of Limestone.

The oil excitement of 1875-76 caused a rapid development of territory along the Tuna valley. The first productive wells were drilled on the farms of Hiram and William Beardsley. These found oil in paying quantities and in a few months the valley was dotted with derricks. In the fall of 1878 there were more than 250 wells in Carrollton township alone.

Explorations northward began in 1876, when the Allegany oil co. put down a well on the premises of J. G. and E. M. Johnson in Allegany township. Oil in paying quantities was obtained, and rapid development followed. The discovery of oil in the Woodmancy well near Allegany village in 1878-79 opened up a

new pool which was still further developed 10 years later. The wells here are small producers and appear to mark the northern limit of oil territory in the county.

Pipe-lines[a]

In 1873 J. H. Dilks organized the Olean petroleum co., establishing headquarters at Olean. The construction of a pipe-line to New York was immediately begun, and on Thanksgiving day of that year the first oil was pumped through a section of pipe 14½ miles in length. In 1876 this company was succeeded by the Empire transportation co. In 1879 the United pipe-line, afterwards the National transit co., bought the stock and interests of the Empire co. and began the erection of storage tanks.

At one time there were in the vicinity of Olean 300 tanks having a capacity of 9,000,000 barrels. From Olean as an initial station, two six-inch lines now extend to the seaboard through which 35,000 barrels of oil can be delivered each day.

Refining

In 1877 a refinery of two small stills was erected by Mr Eastman on the site now occupied by the Acme works. This soon passed into the hands of Wing, Wilbor & Co., who added a 500 barrel still. In the following year the property was purchased by the Acme oil co. of Titusville, Pa., which immediately began the enlargement of the works. At the close of 1885 the number of stills had increased to 25, with boilers, tankage and other accessories in proportion. In 1894 an additional plant was erected to refine the Ohio crude oil. The plant now owns 49 stills and 153 tanks and refines 5000 barrels of oil a day.

Explorations for gas and oil

In the northern half of the county several borings have been made for gas and oil, none of which have been commercially profitable. In the greater number of instances either no records have been kept; or if kept, are too incomplete and inaccurate to be of much value. The well drillers, usually imported from the oil

[a] Information from W. M. Irish, gen. mgr. Acme works, Olean, N. Y.

regions of Pennsylvania, have disregarded everything except sandstones, in which they had been accustomed to find oil or gas, and so valuable stratigraphic information has been lost. In a few instances owners of the wells have been disposed to withhold information, specially if the well was a "wildcat" in a hitherto unexplored district. This inability to procure accurate information has left gaps in our knowledge which make the task of correlating the strata already recognized in Erie co. with those occurring in wells farther south exceedingly difficult. The records which follow are believed to be accurate within the limits claimed.

Gowanda wells

At Gowanda two wells have been sunk on the Cattaraugus co. side of the Cattaraugus creek. The following original record of the old Vinton well kept by the driller, Mr J. D. Rickerson, differs slightly from the one already published.[a]

Vinton well

Completed Mar. 23, 1883

Salt water	at 250 feet	Top of Corniferous limestone	at 1580 feet
Gas and oil	458	Water	1580
Oil	904	Well finished in water	1700
Gas	1006		

Cased to 100 feet.

This record places the horizon of the Corniferous limestone at 1580 feet, 290 feet deeper than in the record furnished by Mr Vinton.

In July 1897 a well was put down on the Ross farm two and one half miles east of Gowanda near the junction of the two branches of Cattaraugus creek. The following record was furnished by Mr Charles Howland who was on the spot while the well was being drilled and who kept careful records of the depths.

Gas at 246, 570, 598 and	1193 feet	Green oil	at 1707 feet
Corniferous limestone	at 1505	More green oil	1765
Amber oil	1626	Bottom of well	2060

a See author's paper, 5th an. report of N. Y. state geologist, 1885.

The well was shot at 1626 and 1710 feet producing a heavy oil having the color of new cider. At the time of my visit in August 1897, the well was reported to contain 100 feet of oil resting upon 900 feet of water. Mr Howland thinks the well would have yielded better if shot at 1765 feet. As it has not been pumped, the daily yield has not been ascertained.

In the Zoar gas field on Cattaraugus creek, six miles south of Springville, a well[a] on the Cattaraugus co. side passed through

Drift	80 feet	Show of oil and gas	at 1865 feet
Top of Corniferous limestone	at 1700	Depth of well	1950

The well has no gas worth piping.

The Kelly well across the creek in Erie co. found.[a]

Corniferous limestone	at 1500 feet	Amber oil and salt water	at 1760 feet
Green oil and gas	1725		

The two Gowanda wells and the Zoar wells quoted above are the only borings in the northern part of the county where a fair showing of oil has been found. The amount thus far discovered is, however, insufficient to warrant the belief that oil exists here in paying quantities.

The data furnished by these well records, which are believed to be as reliable as can be obtained by the ordinary methods of drilling and measuring, show the horizon of the top of the Corniferous limestone to lie at Gowanda about 1500 feet below the surface. The top of the corniferous at Buffalo creek is approximately 573 feet above tide. The elevation of Gowanda station is 772 feet. Assuming the air line distance between these points as 27 miles, the average dip of the top of the Corniferous is approximately 48 feet to the mile.

Wells have also been put down at Snyder's schoolhouse, lot 50, town 5, range 8, and at Smith's Mills nine miles west of Gowanda. No record of these has been preserved beyond the fact that the first was about 1000 feet deep.

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[a] See author's paper, 16th an. report of state geologist, 1896.

The Alder-bottom well

This well was located on lot 22, range 9, township of Leon about six miles west of Cattaraugus village. Mr J. W. Stearns who drilled the well informs me that the drill encountered nothing but shales till the Corniferous limestone was reached at 2255 feet. Drilling was stopped in the Niagara shales, as he believes, at a depth of 3000 feet.

Other borings

In December 1897 a well was sunk at East Otto by Mr Arthur Richardson. The well is reported to have stopped in water at 2753 feet. No record has been obtained.

At West Valley on the Buffalo, Rochester and Pittsburg railroad a well was sunk for gas several years ago without success. No record has been preserved.

In the vicinity of Ellicottville four wells have been drilled, all of which have proved barren. Three of these are located in what is known as the Somerville valley, two miles east of the village. Well no. 1 of this group gave, according to Mr Hickey, the contractor, the following approximate record.

First sand, with a little gas at about	250 feet	30 feet of black shale with some oil	at 1340 feet
Second sand	725	Sand	1600
Third sand	1050	13 feet of shells	1790
		Bottom of well	1803

The well furnished very little gas.

Well no. 2, one mile east of no. 1, found 35 feet of sand having a show of oil at 475 feet. Drilling to 1809 feet disclosed no further oil or gas.

A fourth well was put down in the latter part of 1897, three fourths mile west of the village without finding gas. This well was 1651 feet deep.

Four wells have been drilled in the vicinity of Franklinville, one of which was 2500 feet deep. The Simonds well 2400 feet in depth gave a small amount of gas, but not enough to be of commercial value. Of the Ogilvie well located east of Franklinville no information was obtainable. All these wells were practically barren.

In the townships of Conewango and Randolph several borings have been made, the records of which are meager and unsatisfactory. The well drilled at Conewango in 1865 is reported to have been 840 feet deep and "dry." In the vicinity of Randolph five borings are reported. One on the Albert Gasman farm in Randolph village is said to have passed through a white pebble sand containing some oil. Gas from this well was piped to Mr Gasman's house and supplied it with fuel for two or three years. The gas horizon is given as 800 feet. Another well sunk for water near the Chamberlain institute failed to reach the bottom of the drift at 400 feet.

Two wells are located at East Randolph and two on the Scudder farm one mile southeast of Randolph. No records of these could be obtained.

Mud creek field

A group of four wells is located on the county line, partly in Chautauqua co. and partly in the southwest part of the town of Randolph. One well was drilled 36 years ago, the others in 1896-97. The following record was furnished by Mr J. E. Hazard of Randolph.

Well on Walker farm, s.w. part of Randolph township

Rock	at 30 feet	Oil sand 23 feet	at 330 feet
Shale and sand	to 170	Gas in shale	400
A little gas in sand and shale	at 170	Sand (40 feet) (Dewdrop?)	490
		Best gas	502

Gas estimated to be 50,000 feet a day.

Another well just on the Chautauqua co. side of the line is said to furnish 100,000 feet a day.

Mr John W. Knox reports the rock at Mud creek to dip to the east.

Several borings have been made near Little Valley of which no record has been kept. One was located two miles west of the village and was barren. The well on the A. B. Chase farm was drilled to 1400 feet and is said to have yielded, at one time, a strong flow of gas. Another well on the Winship farm was drilled to the depth of 2000 feet but proved to be entirely barren.

Little Valley township

A boring which at one time gave promise of a remunerative supply of gas was located on the farm of Mr John E. Leach about one and one half miles northeast of Elkdale station. Samples of the drillings were shown me by Mr Leach from which the following notes were taken:

Sandstone	130 to 140 feet	Blue gray shale	1160 feet
Sandstone	200 to 240	Blue gray shale	1275
Calcareous sandstone	300	Harder blue gray shale	1290
Calcareous sandstone	350	Shale	1450
Argillaceous sandstone	600	Black shale	1488
Hard argillaceous sandstone	620	Blue shale	1530
Pocket of gas in hard argillaceous sandstone	630	Black shale	1590
Hard argillaceous sandstone	850	Gray sand with some oil	1740
Softer argillaceous sandstone	884	Gas which was drowned out by salt water	1980

Sufficient gas was obtained from the lower level to furnish four stoves for a year. The pocket found at 630 feet gave a large flow for 16 hours and then ceased almost entirely.

Salamanca township

A well on the Rich farm, lot 18, township of Salamanca is said to have furnished a small flow of gas. No record has been preserved. Wells on both sides of the valley below Salamanca have proved entirely barren.

The following record shows the conditions found in this vicinity.

Salamanca centennial well, Oct. 28, 1876 [a]

Record by H. A. Darrow

Well mouth A. T. 1554 feet

Conductor 9 feet

Gray slate and shells	441 to	450 feet	Gray slate with shells	784 to	1120 feet
First s. s.	450	455	Third s. s.	1120	1138
Gray slate	455	750	Gray slate with hard shells	1138	1325
?	750	780			
Second s. s.	780	784			

Cased at 241 feet. A small quantity of gas at 900 feet. Unremunerative.

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a Pa. second geol. survey 14, p. 101.

Peth well. Near Great Valley, N. Y.

Drilled by O. A. Knox, Bradford, Pa.

Record from R. F. Gilman, Great Valley

Drive pipe	66 feet	Gas and 20 ft sand	at 650 feet
Gray sand, 6 ft	at 430	Slate	to 1570
Dark sand, 15 "	470	Sand, 30 ft with no gas	at 1570
Slate and shells, 40 ft			
A little gas at	570		

Completed at 1650 feet.

This well furnished a small but permanent flow of gas which has not been utilized.

Two wells producing a small quantity of gas are located on the land of Mr Ostrander at Killbuck. They are not commercially profitable.

The Humphrey field [a]

During the year 1897 nine wells were put down in the southwest part of the town of Humphrey, in four of which some oil was found.

The successful wells are located on lots 50, 51 and 59, and on Mar. 1, 1898 were producing altogether about 10 barrels of oil a day. At that time a total of 400 barrels had been run into the pipe-line.

Record of well no. 1, Ed. Guthrie farm, on lot 51, Humphrey, belonging to the Union oil and gas co.

Sunk in May 1897

Record from B. C. McIntyre

8 inch drive pipe through gravel and quicksand	85 feet	Top third sand	at 1236 feet
12 ft white sand with a little oil and gas at	310	Sand and shells	1236 to 1272
First regular sand, gray, 25 ft thick with a little oil and salt water	at 510	Oil, and gas enough for boiler	at 1272
Top second sand	1035	Chocolate (Bradford?) sand	1272 to 1300
		Sand and shale mixed, with 12 ft of black shale full of oil at the base, to the bottom of well	1372

The bed-rock first reached by the drill was a white, flat-pebble conglomerate.

[a] A test well was bored in Humphrey about the year 1878 by Golden, Fowler & Humphrey. The well was 1500 feet deep and barren.

Well on the Childs farm, belonging to Union oil and gas co.

Record from B. C. McIntyre

Mouth of well approximately 1500 feet A. T.

To bed-rock, a soft conglomerate	15 feet
First gray sand, 20 ft	at 580
No second sand	
Top third sand	at 1305
Shells and sand	1305 to 1345
Oil and gas in chocolate colored sand (Bradford?) 12 ft thick	to 1357 feet
Total depth, finishing in shale	1403

Bear Hollow well, belonging to the Orchard park oil and gas co.

Record from B. C. McIntyre

Elevation of mouth of well approximately 1800 feet A. T.

Bed-rock	at 20 feet
Cased	to 220
Top of Bradford sand	at 1417
Bottom of Bradford sand	at 1438 feet
Black (McKean?) sand, 30 ft	1618

The Bradford sand yielded gas and about a barrel of oil a day. Three additional wells were drilled Mar. 1, 1898.

Well at Ischua

Record from E. J. Fish by C. E. Banfield

This well is located three quarters of a mile east of the village in the s. e. corner of lot 8, Ischua township.

First sand containing a small amount of black heavy oil and a little gas	from 140 to 160 feet
Shells with a little gas	at 750
Light colored shales with some shells	750 to 1150 feet
Black shale from	1150 1725
Coarse red sand without gas or oil	1765
Total depth	1802

Well unproductive.

Hinsdale

A well put down about 20 years ago on lot 48 near Hinsdale village is reported to have given a small showing of oil. Another on lot 12 was entirely dry. Five years later a well was bored near the Western New York and Pennsylvania depot which gave a large flow of gas for several years but has now ceased to produce. This well was 1200 feet deep. Another, one mile south

of this, struck a small flow of gas at 1200 to 1300 feet below the surface.

During the summer of 1896 a well was bored on the edge of Hinsdale township near the county line, not far from Cuba. Neither gas nor oil was found.

About 32 years ago a well was put down by Mr T. P. Snyder on the old Indian reservation near Cuba in Allegany co. Mr Snyder reports a small showing of gas and heavy oil at about 370 feet. As the well was drilled wet and not properly cased, its possibilities were never ascertained. Well no. 2 drilled by Mr Keeney gave some gas but no oil.

Southern tier of townships

All the townships bordering upon the Pennsylvania line have furnished small amounts of both gas and petroleum. The territory in which these products occur in commercial quantities is limited almost entirely to the townships of Carrollton and Allegany, which have produced more than nine tenths of all the oil thus far marketed from the whole county.

A small oil field also occurs in the southern part of Olean township and a few productive oil wells have been recently found in Red House.

South Valley township

Near Onoville two wells have been sunk to the third sand at a depth of 1200 or 1500 feet. One of these was barren; the other gave gas which, if used, would supply three or four families. A third well was in process of drilling in April 1898.

Red House

The discovery of gas in the Red House field was first made in February 1891, the principal horizon being the second sand. The original confined rock pressure in the best wells was 225 pounds, which had, in August 1897, fallen to 100 or 125 pounds. My informant, Mr E. W. Lewis of Bradford, estimated the total output of the Red House field at that time to be 30,000,000 cubic feet a month.

A small portion comes from the Rice Brook field, but the greater part is furnished by seven wells in the eastern part of the town. One or two wells on lot 44 supply about 210,000 cubic feet a day additional to the Smith chemical co. of Bradford. The gas from Red House and Rice Brook also supplies the villages of Limestone, State Line, Carrollton and West Branch. In addition to 376 stove connections, it furnishes fuel for the two large boilers at the Limestone tannery, for the power house of the Olean, Rock City and Bradford electric railway at Red Rock, for four oil well boilers and for the 24 retorts of the Chemical works at West Branch.

A well with an estimated flow of 9,000,000 feet of gas a day was completed in April 1898, in Pennsylvania, just south of lot 1, in the extreme southeast part of this township. No borings have been made in Red House to ascertain whether the pool extends into this state.

Well records

Information from Mr Miner Wellman, Friendship, N. Y.

Messrs Doherty, Wellman and Corbin have producing gas wells on lots 6, 13, and 14 Red House township. The well on the west part of lot 13 had an original rock pressure of 227 pounds and a measured volume of 1,000,000 cubic feet a day.

Another southeast of the middle of lot 14 had an original rock pressure of 200 pounds with a measured volume of 9,200,000 cubic feet a day. A well on the n.e. corner of lot 13 gave a pressure of 190 pounds and a volume of 4,200,000 cubic feet. On the south part of lot 6 a well gave a pressure of 145 pounds with a volume of 3,500,000 cubic feet a day. The wells on the east side of lot 22 are barren.

The gas horizon here is thought to be the second sand at about 800 feet below the surface.

Well no. 1, s.e. corner lot 23, Red House township, 200 ft from each boundary line

Record from Devonian oil co.

Conductor	36 feet
Drive pipe	301
Rice Brook sand, top	956
Rice Brook sand, bottom	995
Red sand, barren	1195 feet
No third sand or signs of any	
Bottom of well	at 1308

Record of well no. 1, lot 21, town 1, Red House township, belonging to Mrs Mary Fitz, Salamanca, N. Y.

Authority, Mrs Fitz

Drive pipe	77 feet	Sand and slate	at 680 feet
Cased	to 406	Sand and slate with gas	to 695
Salt water	at 405	Stray sand with oil	at 715
Salt water	to 450	Sand and slate	780
Sand	at 520	Sand and slate	820
Sand and slate	to 570	Sand with much gas	887
Stray sand	at 630	Bottom of well	952

This well has a rock pressure of 140 pounds and is estimated to give 500,000 cubic feet of gas a day.

Well no. 1 of the Worth oil co. on the C. S. Aldrich farm, lot 12, Red House township

Drilled April 1897

Drive pipe	80 feet	Bottom third sand, red, 4 ft	1068 to 1072 feet
Casing	523	Bottom of well	1072
Top third sand, white, 14 ft	1054 to 1068		

Well no. 2, same lot, April 1897

Casing	407 feet	Bottom third sand	1119 feet
Top third sand	1099	Bottom of well	1119

Well no. 19, Red House township

Top red sand	1142 feet	Bottom red sand	1162 feet

Well on Joseph Renaldi farm, s.e. cor. lot 45, Red House township

From Devonian oil co. Bradford, Pa.

Conductor	16 feet	Brown sand	at 1095 feet
Casing	300	Top Bradford sand	1359
Chipmunk (?) sand	at 680	Bottom of Bradford sand	1429
Top second sand	1049	Bottom of well	1562
Bottom of second sand	1059		

Well no. 1, Quaker run oil and gas co. lot 44, Red House township

Drilled December 1890-February 1891.

Conductor	32 feet	Brown third sand 1224 to 1279	55 feet
Casing	311	Pure soft slate 1279 to 2509	1230
White gas sand 980-1054	74		

Fresh water and fair gas in white (second) sand

Well no. 2, lot 44, Red House township, April 1891

Conductor	28 feet	Brown or third sand 1235 to 1298	63 feet
Casing	280	(Show of oil in third sand)	
Top white "gas" sand 1050		Slate and shells 1298 to 1368	70
Bottom white "gas" sand 1135	85		

Well unproductive.

Well no. 3, lot 43

Drilled April-June 1891

Records from the Devonian oil co.

Conductor	18 feet	Brown (third) sand, some gas, 1237 to 1253, sample showed oil	16 feet
Casing	280	Slate 1253 to 1260	7
Slate 18 to 980	962	Slate and limestone shells 1260 to 1270	10
Brown sand 980 to 992	12	Slate and limestone shells 1270 to 1280	10
White (second) sand 992 to 1050	58		
White sand and shells 1050 to 1084	34		
Slate and limestone shells 1084 to 1237	153		

At 1246 feet the sand was loose and furnished gas which would burn six feet above the top of the casing. The well was commercially unproductive.

Well no. 4, lot 44, Red House township

Drilled July-August 1891

Conductor	23 feet	Shells and slate 1185 to 1240	55 feet
Casing	340	Brown and gray sand mixed, 1240 to 1255	15
Brown sand 980 to 1011	31	Slate 1255 to 1285	30
White (second) sand with gas 1011-1085	74	Coarse brown sand 1285 to 1305	20
Slate and shells 1085 to 1125	40	Soft slate 1305 to 1318	13
Pure slate 1125 to 1185	60		

Completed at 1318 feet.

Good flow of gas at 1011 to 1030 feet.

Petroleum

One small oil pool has been developed in this township, located on lots 19, 12 and 20. The productive horizon is in the second sand which here is found at a depth of 1050 feet. The wells produced at the start from 10 to 50 barrels each, and were in May 1898 yielding an average of five or six barrels. Small quantities of oil are also reported from other parts of the township but nowhere in paying quantities.

The Chipmunk field

This field takes its name from Chipmunk creek along which the first paying wells were found. It includes a region, the limits of which are not yet clearly defined, extending from the juncture of Tuna creek with the Allegany river southeastward and including the east-central part of Carrollton and the west-central part of Allegany townships south of the Allegany river.

The oil occurs in a stray sand or sands, considerably above the regular sand of the Bradford and Kane pools.

The first well in this field was a "wildcat" boring by a Mr Simons, on the Homer farm, in 1880. A small amount of oil was found at about 600 feet; but as no oil horizon was then known so near the surface, it was not thought worthy of attention. The well was continued to the third or Bradford sand, and no further oil being found, was abandoned.

In April 1895, Dr J. P. Colegrove of Salamanca, put down a trial well on the Mike Kelley farm. Gas was found at 600 feet, and a show of oil, which at the time was considered worthless, at 615 feet. No oil was found in the third sand. A second well was sunk 100 rods away on the Corts farm with similar results, a small quantity of oil being found at about 615 feet and the third sand being barren. A third well on the Mary Kelley farm showed the same conditions as the earlier borings.

The fourth well, still farther north, was drilled to the depth of 1200 feet. Gas and oil having been noticed at 700 feet, the hole

was plugged and shot at that depth. The well started off with a flow of 30 barrels a day and continued to flow for a year and four months.

This was the first producing well in the field. Wells 1, 2 and 3 were then plugged and shot in the same sand at about 615 feet and all proved to be good producers. Later on a number of wells were put down on the Homer farm near the Simons well of 1880, and were all productive.

In May 1896 a well on the King farm found oil in a stray sand above the Chipmunk sand. This started off with 100 barrels a day and produced 15,000 barrels the first year.

The first well on the Indian reservation at South Vandalia, was sunk on the flat near the village in March 1897. Some oil was found in a stray sand at 352 feet, and at 392 feet oil which flowed 1000 barrels in 24 hours.

The oil throughout this field appears to be scattered through several sands of which the first, at about 615 feet, is the most productive. In places it appears to be divided into two distinct divisions, sometimes including salt water between. The oil is of an amber color and of excellent quality, being readily distinguished from the Bradford oil which is greenish. The Chipmunk sand is reported to dip south, and the Bradford sand southwest. The former is regarded by oil men as a stray sand, and is probably distinct from other oil horizons previously found.

Recent borings go to show that the sand extends much farther to the south than was at first supposed, and it may at some future time, be correlated with an already known horizon. At present the matter is in doubt.

The following wells are selected as giving a fair section of the Chipmunk field in a s.e.—n.w. direction. The records were furnished by Dr J. P. Colegrove of Salamanca who has been actively prominent in developing this field.

Wells in Chipmunk field

Michael Kelley well no. 1, Chipmunk valley, 3½ miles south of Allegany river

Cased off	at 353 feet	Third (Bradford) sand, chocolate colored slate	at 1140 feet
First gas sand, grayish white	600	Kane sand (black)	1420
Oil	615 to 655		
Second sand	at 790		

Other rocks, shales and thin, blue gray or olive gray sandstones.

Well on the John King farm, down the creek from the preceding

Same elevation

Well no. 1 casing	270 feet	Shale for	30 feet
Gas	at 570	Second sand	629
Top oil sand, 24 ft	575	Then same as no. 1.	
Bottom oil sand	599		

Devonian oil co.'s well no. 9, King farm

Sunk Aug. 26, 1896

Drive pipe to rock	48 feet	Top oil sand	542 feet
Casing, fresh water	386	Bottom of oil sand	562

Stopped in oil sand.

This well has produced between 6000 and 7000 barrels of oil.

King no. 8 (500 ft east of no. 9)

Drive pipe	180 feet	Top oil sand	541 feet
Casing	400	Bottom of oil sand	562½

Did not go to the second division of the first sand.

This well produced 15,000 barrels the first year. In August '97, when the well was one year and four months old, it was still flowing 15 barrels a day.

O'Mara well, next well north of King well

Casing for fresh and salt waters	460 feet	Top second layer of first sand	608 feet
Top oil sand	550	Bottom second layer of first sand	613
Bottom oil sand	565		
Shale	565 to 608		

Gave four barrels a day.

John McCaffery well, 2 miles further north, near Chipmunk creek, by W. N. Y. & P. R. R. station

Casing (fresh and salt water)	441 feet	Bottom of sand	525 feet
Top of sand	498	Slate	to 550
		Oil sand	550 to 575

Well no. 1, Seneca oil co. on the Indian reservation one-half mile north of the creek near the river

Casing for fresh water	235 feet	Bottom of oil sand	443 feet
Top oil sand	425		

This well flowed 50 barrels at the start and in August 1897 flowed 12 barrels a day.

Well no. 10, same company. Further north but not near the river

Drift	300 feet	Oil sand	at 352 feet
Casing, for salt and fresh water	335	Oil sand, gray slate color	to 362

In August 1897 this well was flowing 10 barrels a day.

Just north another sand is found at 400 feet but it is not reached in this well.

From well no. 1 Kelley to well no 10, there is 121 feet fall in the stream.

Crawford farm, Indian reservation

Cased off to rock	287 feet	Bottom second sand	at 509 feet
Top oil sand	467	Slate	to 1035
Bottom oil sand	476	Oil sand, gray slate color	1035
Shale, 19 ft	to 495	Well drilled into it to	1068
Second sand	495		

This well was not shot.

One well in this field, Seneca no. 5, started at 500 barrels.

From Worth oil co.

Dougherty well, 76

Drilled September, 1896

Located near the Kelley well

Conductor	23 feet	Top of brown sand	771
Casing	300	First oil	780
White sand (first show of oil)	420	(Third screw good sand)	
White sand with a little gas which was exhausted in drilling well	at 625 feet	Bottom of well	801

Shot 780 to 788 feet.

Dougherty well, 75

Drilled August 1896

Conductor	38 feet	Gas	763 to 770 feet
Casing	417	First oil	780
Top brown sand	763	Bottom of well	794

Dougherty well, 67

Drive pipe	55 feet	Fifth screw, salt sand, no water	613 to 615 feet
Casing	404 to 411	Sixth screw, good sand, no oil	
Top brown sand	593	Seventh screw, good sand, no oil	619½ to 624½
First screw, good sand, dry	to 598	Eighth screw, best oil	624½ to 630
Second screw, same sand	598 to 603	Ninth screw, broken sand and slate	630 to 636
Third screw, better sand	603 to 608	Slate	" 656
Fourth screw, very little oil	608 to 613	Sand	at 656
		Sand	to 662

The Salamanca cooperative co. have two wells at Riverside, one of which furnishes 30 barrels a day natural and the other about 6 barrels.

The record of one of these is given below.

Drift	300 feet	To pay sand 200 ft	720 feet
To first chipmunk sand 220 ft	520	To bottom pay sand (Rice Brook?) 20	740

There are in the Chipmunk field about 300 wells and active drilling is still going on. Dr Colegrove estimates the production of this pool for the year ending July 31, 1897 at 600,000 barrels.

The Rice Brook field[a]

This term is locally applied to the region west and southwest of Irving's mill, but more particularly to an oil pool located on lots 52, 59, 60, 71 and 72 Carrollton township. The following sections show the characteristic stratigraphical features.

a The first well in this field was drilled by North & Dunham on lot 39, in November 1898, and produced about 15 barrels a day. The King oil co. found the next producing well on lot 71, west of the N. & D., getting an 80-barrel well. The third well belonged to the Test oil co., on lot 60, and started off at 100 barrels.

Well on O'Neil farm, lot 71, township of Carrollton

Drilled January 1897

Casing	279 feet	Slate with salt water	990 to 995
Top Rice Brook sand	at 983		
Bottom Rice Brook sand	990		

The upper six feet of the sand was mixed with pebbles, the rest of the stratum finer and darker colored. Oil came in at 983 feet, filling the hole 400 feet and giving in addition eight bailers of salt water during the first night. At the end of 24 hours the well had furnished 40 barrels of oil. Three weeks later the production had dropped to 8 barrels a day.

Well, lot 59, same township

Casing	259 feet	Top of sand (Rice Brook)	1082 feet
Dark sand 40 to 50 ft thick	at 875	Drilled	to 1090

The oil sand had four feet of pebbles at the top with an equal depth of darker sand without pebbles below. The well filled 300 feet with oil in two hours, and produced 30 barrels the first day without shooting.

Well no. 1, Worth oil co., lot 60, township Carrollton

From Devonian oil co.

Rice Brook sand, top	1039 feet	Bottom of well	1045 feet
Rice Brook sand, bottom	1043		

Well no. 4, same lot

Drilled July 1897

Casing	260 feet	Top salt sand	1052 feet
Top Rice Brook sand	1043	Bottom of well	1057

Well no. 1, Rumsey farm, on lot 44, Carrollton township near mouth of Rice Brook

Owned by the Devonian oil co. Sunk May 1896

Record from S. P. Heasley, driller, Tuna Creek, Pa.

Drift	240 feet	Cased	to 565 feet
Cement gravel	at 284	A little oil	at 580
Drive pipe	285	Gas, and oil which flowed	800
Oil and salt water	480	Drilled	to 882
With good sand	to 555		

In June 1897 the well was drilled to 900 feet and flowed with an increased amount of oil.

Mr W. M. Kincaid of the Devonian oil co., Bradford, gives me a synopsis of a well on the Rumsey tract which appears to refer to the same boring. According to this the sand occurred as follows:

First sand	at 480 feet	Top third sand	at 730 feet
Bottom of first sand	555	Bottom of third sand	740
Top second sand	570	Shell	811
Bottom of second sand	580		

Mr Rathbone of the firm of Mallory & Rathbone, Bradford, Pa. reports the following results of levelings to ascertain the dip of the Chipmunk sand near Irving's mill: from Chipmunk to Irving the dip is west 50 feet to 600 rods. The next 400 rods west shows a dip of 41 feet. Northwest from Irving's mill the dip is 28 feet in 275 rods. The total dip southernly measured between the McCaffery farm, lot 16, and the North and Dunham well on lot 59 Carrollton township was south 119 feet in 1200 rods.

According to this, the rock dips from Irving in all directions but greatest toward the east.

Other borings in Carrollton Township

Well no. 12, *Matteson oil co.* (*on hill*)

Conductor	24 feet	Oil	1230 feet
Casing	300	Rotten sand	1264
Chipmunk sand (with gas)	1223	Total depth	1297

Mants well, Tony White farm, lot 27, *north end, in a valley*

Conductor	42 feet	Total depth	620
Casing	390	Torpedoed with 40 quarts	at 587
Second sand	586		
Oil	to 605		
Good sand	to 615 feet		

A small oil pool has been developed on lots 11 and 12 Carrollton. It is owned by the Johnsons of Bradford, Pa.

Well top of hill, lot 4

Salt sand at 1005	1005 feet	Chipmunk sand	23 to 50 ft usually 25 to 28 ft	at 1223

Second sand, 175 feet lower.

From top of this to top of Bradford sand 485 feet.

Lot 5, Carrollton township (Flatstone)

Authority, S. P. Heasley

Conductor	17 feet	Chipmunk sand	660 feet
Casing	426	Total	704

Matteson well, no. 3, same lot

Authority, S. P. Heasley

Conductor	25 feet	Oil sand	790 feet
Casing	585		

Matteson well, no. 9, lot 3, Carrollton township (on hill)

Conductor	34 feet	Sand	to 1358 feet
Casing	376	Total	1387
Chipmunk sand (?)	1334		

A good well.

Will Beardsley farm. Near center of lot 17, Carrollton township

Drive pipe	178 feet	Good sand	to 1080 feet
Casing	348	Total depth	1134
Bradford sand	1068		

Burger well, no. 2, "Bootleg tract" lot 44, s.e. cor.

Conductor	57 feet	Best sand	685 feet
Drive pipe	145	Bottom oil sand	685
Casing	461	Total depth	714
Oil sand	659		

Burger well, no. 3

Drive pipe	202 feet	Bottom oil sand	652 feet
Casing	404	Total depth	674
Oil sand	620		

In a well at about the level of the railroad track at Limestone, 1410 feet, Chipmunk sand was found at 540 feet, Bradford sand 300 feet lower.

T. B. Crary well on Johnson farm, middle lot 40, Carrollton township on the west side of Tuna creek, near Limestone, N. Y.

Record from S. P. Heasley, Tuna Creek, Pa.

Soil	27 feet	Bottom third sand	1196 feet
Casing	368	Total depth	1379
Top third sand	1160		

Kellogg well, next farm, same lot

Drilled April 1896

Soil	32 feet	Best sand	1273 feet
Casing	374	Bottom third sand	1280
Top third sand	1268	Total	1357

Shot 1268 to 1280: good results.

Well on Bald hill near Limestone, eastern side of Tuna Creek

Elevation of the top of this hill is 2250 feet A. T. Exact elevation of mouth of well not ascertained, but about 70 feet lower.

Casing	385 feet	Bottom of sand	1290 feet
Third sand	1250	Total	1330
First oil	1276		

ALLEGANY TOWNSHIP[a]

This township has proved exceedingly productive of petroleum. The best wells have been obtained in the northerly extension of the Bradford field on the head waters of Four Mile run, in the vicinity of the Olean Rock city, and southwesterly to the Pennsylvania line.

The Allegany pool situated south and west of Allegany village, on both sides of the Allegany river, although giving smaller wells, has yielded a large amount of oil and has been on the whole, a source of great wealth to the township.

The wells in this field yield only four or five barrels a day, but maintain a very constant flow for a long time. Wells producing as low as two barrels a week are considered paying.

Recent developments along lower Four Mile creek indicate that the Allegany pool is connected with the Bradford field or at least only separated form it by one or more "dry streaks."

[a] Historical. The first well drilled in this field was that of Peck & Freeman on the Woodmancy farm in 1878 (?). The well was apparently dry. A second well, which also proved barren, was sunk on the Hull or Garr farm, about a mile south of the first, in the latter part of the same year or in the spring of the year following. The third well, on the Freeland property, produced some oil.

The newly discovered Chipmunk field discussed elsewhere, has found some of its best wells in this township. At the date of writing (May 1898) developments are in progress near the Indian reservation which seem to indicate the extension of the Chipmunk field northeasterly along the Allegany river. Whether this is so, or whether this is an entirely new pool, has not yet been satisfactorily determined. The record of wells in the Chipmunk field are given in connection with others in the township of Carrollton.

Below will be found characteristic sections in the Allegany and Four Mile regions.

Frank Stevens well, near 400 mile post J. C. Erie R. R., 2 miles west of Allegany

Well approximately 3 feet lower than the rail

Record only approximate

To rock	110 feet	To second sand	about 700 feet
To first sand	about 400	To third sand	1005

Third sand is about 15 feet thick.

Mohr well, south of Allegany

Casing	570 feet	First show of oil	1002 feet
First sand (gas on top, salt water at bottom)	at 500	Better show of oil	1008
		Fair show of oil	1026
		Black sand	1039
Second sand and gas	800	Bottom of black sand	1052
Third sand	995	Depth of well	1099

H. Gillitts well no. 2, Allegany

Drive pipe	122 feet	Sand	995 feet
Casing	292	Bottom of sand	1005
First sand	434	Depth	1061

The best well sunk here is on the Worthington farm west of Allegany. This started at 80 barrels and is now flowing at one to one and a half barrels a day. No gas to speak of in this territory.

J. H. Carl well, Allegany, Oct. 1890

Top third sand	1139 feet	Light show	1184 feet
Light show of oil	1145	Light show	1190
Smells stronger	1151	Poor	1196
Better	1157	Bottom of sand	1226
Poor	1172	Depth of well	1247

Cary well, no. 1

Drive pipe	112 feet	Full of oil	at 1000
Hard water sand	180 to 230	Well filled 300 ft with oil in 24 hours	
Casing	230		
First sand	442	Top third sand	1017
Second sand	700	Bottom third sand	1106
Stray sand	966 to 1000	Bottom of well	1124

Quirk well, no. 1

Casing	220 feet	Top third sand	983 feet
First sand	425 to 460	Shell	1030
Slush oil, 12 ft, in sand and slate	779	Bottom third sand	1055
Gray sand and gas, 6 ft	939	Bottom of well	1083

Well no. 1, *Bunnell farm, lot* 3, *range* 4, *Allegany township, near the mouth of Four Mile creek.*

Record from Franchot Bros. Olean

Conductor	26 feet	Top third sand	1075 feet
Drift to rock	60	Bottom third sand	1150
Casing	318	Bottom of well	1213

Bunnell well, no. 2 (1890)

To rock	25 feet	Gas	at 1020 feet
Casing	285	Top third sand	1080
Salt water	at 400	Bottom third sand	1157
First sand (gas)	510	Bottom of well	1197
Second sand	800		

Between 1133 and 1153 feet was a very rich oil sand. The top of the third sand for about 15 feet consisted of fine hard sand and shells.

Wells on Four Mile, Allegany township, near Olean, N. Y.

Records from Franchot Bros.

The following wells were accurately measured with a steel tape.

Well no. 2, John Brandel farm, s.w. cor. lot 2, Allegany township

Drilled in 1878

Drive pipe	30 feet	Depth	1332 feet
Casing	346	Torpedoed	at 1305
Sand	1255		

Harbel well, no. 2, lot 2, same township

Drilled March 1878

Conductor	15 feet	Bottom of well	1365 feet
Cased	to 204	Torpedoed	at 1311
Sand	1291		

Harbel well, no. 1

Conductor	24 feet	Third sand	1335 feet
Casing	286	Full depth	1385
Gas	at 1315	Torpedoed	at 1370

Drilled out and shot again at 1325 to 1355 feet.

Well no. 3, John Zaph farm, same lot, Allegany township

Conductor	30 feet	Total depth	1473 feet
Casing	179	Torpedoed at	1427-36
Sand at	1415		

John Frieze well, lot 1

Drilled October 1878

Casing	268 feet	Bottom of well	1420 feet
Sand	at 1300		

Frieze well, no. 4, 1879

Conductor	10 feet	Bradford sand	1040 feet
Casing	372	Total depth	1602

Joseph Falkel well, no. 2, lot 1

Conductor	36 feet	Bottom sand	1439½ feet
Casing	292	Total depth	1505
Top sand	1420		

Wells in this field started off at about 50 to 75 barrels or better, one giving as high as 300 barrels. The production usually drops to 15 or 20 barrels in from three to six months.

Olean

Borings for oil in this township have discovered but one important pool, that known as the Meek's creek or "Haymaker" field, located on lots 3 and 4 of section 1, and lots 1 and 2 of section 5, in the southern part. This group embraces about 200 wells from 1150 to 1170 feet deep, getting oil from the Bradford sand.

The best wells in this pool gave, on the start, as high as 75 barrels a day, but at present the production has fallen to one barrel a day, or less. The greater number which are still pumped fall below a daily yield of one half barrel.

Just southwest of Olean city on lots 8 and 10, is a small pool where three wells yield about a barrel each of oil a day. Borings in the northeast corner of the township have found the edge of the Allegany field, but no producing sands of consequence. A number have given a show of oil in the Allegany sand, but not sufficient to pay for working.

About 30 barren wells are reported in the townships east of Olean city. Four of these are located on lots 1, 2, 6 and 7 of section 4.

A little gas was met in two of these, but not enough to be utilized. The well records which follow were accurately kept and are believed to be reliable.

Record of well no. 1, section 6, Olean township. Belonging to the Devonian oil co.

Authority, W. M. Kincaid

Casing	244 feet	Top third sand (shells)	at 1390 feet
Top Chipmunk sand	at 850	Bottom of third sand (shells)	1451
Bottom Chipmunk sand	880	Bottom of well	1714
Top second sand	990		
Bottom second sand	1051		

The first sand had some oil and gas, and a trace of oil also occurred in the chocolate-colored second sand. From 1007 to 1014 and at 1032 were streaks of gas, the latter burning as high as the walking beam.

Well no. 1, Downing farm, lot 1, range 1, Olean township

Authority, Franchot Bros., Olean.

Casing	470 feet	Bottom of oil sand	at 1700 feet
Gas sand	at 1620	Bottom of well	1749
Oil	1675		

Olean township, Downing no. 3

Gas sand	at 1420 feet	Bottom of oil sand	at 1506 feet
Oil	1473	Depth	1530

Downing no. 17

Casing	300 feet	Bottom oil sand	at 1281 feet
Gas sand	at 1213	Depth of well	1326
Oil sand	1251		

Downing, no. 2

Casing	510 feet	Bottom of oil sand	at 1668 feet
Gas sand	at 1593	Bottom of well	1691
Oil sand	1643	Torpedoed	1628 to 1626

McMullen and Hallock gas well [a]

May 23, 1877

Located on the Loup farm, section 1, extreme s.w. cor. Olean township

Well mouth A. T.	1785 feet	Gray slate with shells	675 to 890 feet
Conductor	16	Second sandstone	890 to 960
Cased	to 196	(?) with sandstones	960 to 1155
Gray shales and slate with thin sandstones	to 625	Sandstone with gas	1155 to 1180
First sandstone	625 to 675	Slate	1180 to 1187
		(?)	1187 to 1120

Third sand with slight show of oil 1220 to 1240.

a C. E. Ashburner, Petroleum and natural gas in New York, 1888, p. 34.

A month after drilling C. A. Ashburner estimated the flow of gas from this well at 24,480,000 cubic feet a day. The life of the well was brief. In 1888 the well produced from two to three barrels of oil a day.

The Bradford oil and gas sand was struck at a depth of 1230 feet, or 1785 feet below the bottom of the Olean Conglomerate.[b]

PORTVILLE

South and east of Hinsdale village and for the most part in Portville township, about 20 borings are reported, in no one of which gas or oil was found in paying quantities. The following reliable record furnished by Franchot Bros., Olean, shows the geological conditions existing in one well.

Mitchell well, no. 1, *lot* 36, *range* 2, *Portville township*

Drift	60 feet
Fresh water	to 272
Salt water	277
Stray (?) white pebble sand 10 ft thick with heavy oil	at 384
Regular first sand, 20 ft with gas	743
Regular second sand, 20 ft with gas	930
Sand, 20 ft. thick, with gas	at 985 feet
Top third sand	1060
Bottom third sand, gas and show of oil	1085
Fourth sand	1214 to 1272
Shale and sand	to 1513
Limestone shale and sand	1513 to 1537
Mixture of limestone, shale and sand	1752½

A heavy pocket of gas was found in a sand at 400 to 420 feet.

In a well on lot 18, s.w. corner of Portville township, according to Mr E. J. Fish, a shell containing some gas was found at about 600 feet.

At 972 feet a gray sand 38 feet thick was pierced which produced about half a barrel of oil a day, and gas enough for a dozen families, if it had been utilized. A third sand two feet thick with no oil or gas occurred at 1125 feet.

Two wells have also been sunk by Mr Comstock of Portville, one just north and the other just south of the boundary line between lots 14 and 15. The well on lot 14 had a small flow of gas

[b] Pa. second geol. surv. 14, p. 99.

at about 1000 feet and a show of oil at 1500 feet. Both wells were valueless.

Mr E. J. Fish reports a well on lot 50, in which a sand 22 feet thick, producing half a barrel of oil a day was found at 960 feet. The well was continued through black shale to 1110 feet and abandoned.

Wells on lots 10 and 11 have produced small quantities of oil and gas, but not enough to be commercially profitable. Barren wells are also reported on lots 1, 16 and 35.

Production of petroleum in New York state

The following summary furnished by Mr John O'Brien, sup't of the National transit co., shows the amount of oil handled by the pipe-lines from Jan. 1, 1897 to Aug. 1, 1898.

Statement of oil produced in New York state from Jan. 1, 1897, to Aug. 1, 1898.

1897	Allegany co.	Cattaraugus co.	Total
January	57,534 69	69,437 84	126,972 53
February	59,681 89	69,798 11	129,480 00
March	63,720 97	84,195 88	147,916 85
April	62,955 54	79,127 36	142,082 90
May	63,076 51	83,473 08	146,549 59
June	62,651 55	84,848 56	147,500 11
July	62,525 21	84,492 05	147,017 26
August	61,660 27	82,772 19	144,432 46
September	55,856 07	81,088 91	136,944 98
October	55,451 66	82,948 47	138,400 13
November	50,681 01	74,606 60	125,287 61
December	56,638 72	76,527 56	133,166 28
	712,434 09	953,316 61	1,665,750 70
1898			
January	54,797 48	70,085 21	124,882 69
February	50,219 08	61,915 31	112,134 39
March	58,321 58	72,552 60	130,874 18
April	54,505 69	67,604 97	122,110 66
May	56,416 80	69,539 91	125,956 71
June	57,260 82	70,097 98	127,358 80
July	52,924 12	65,087 19	118,011 31
	384,445 57	476,884 17	861,328 74

In addition to the above, about 5000 barrels not handled by the National transit co. are produced every month on the Reservation lands in Cattaraugus co.

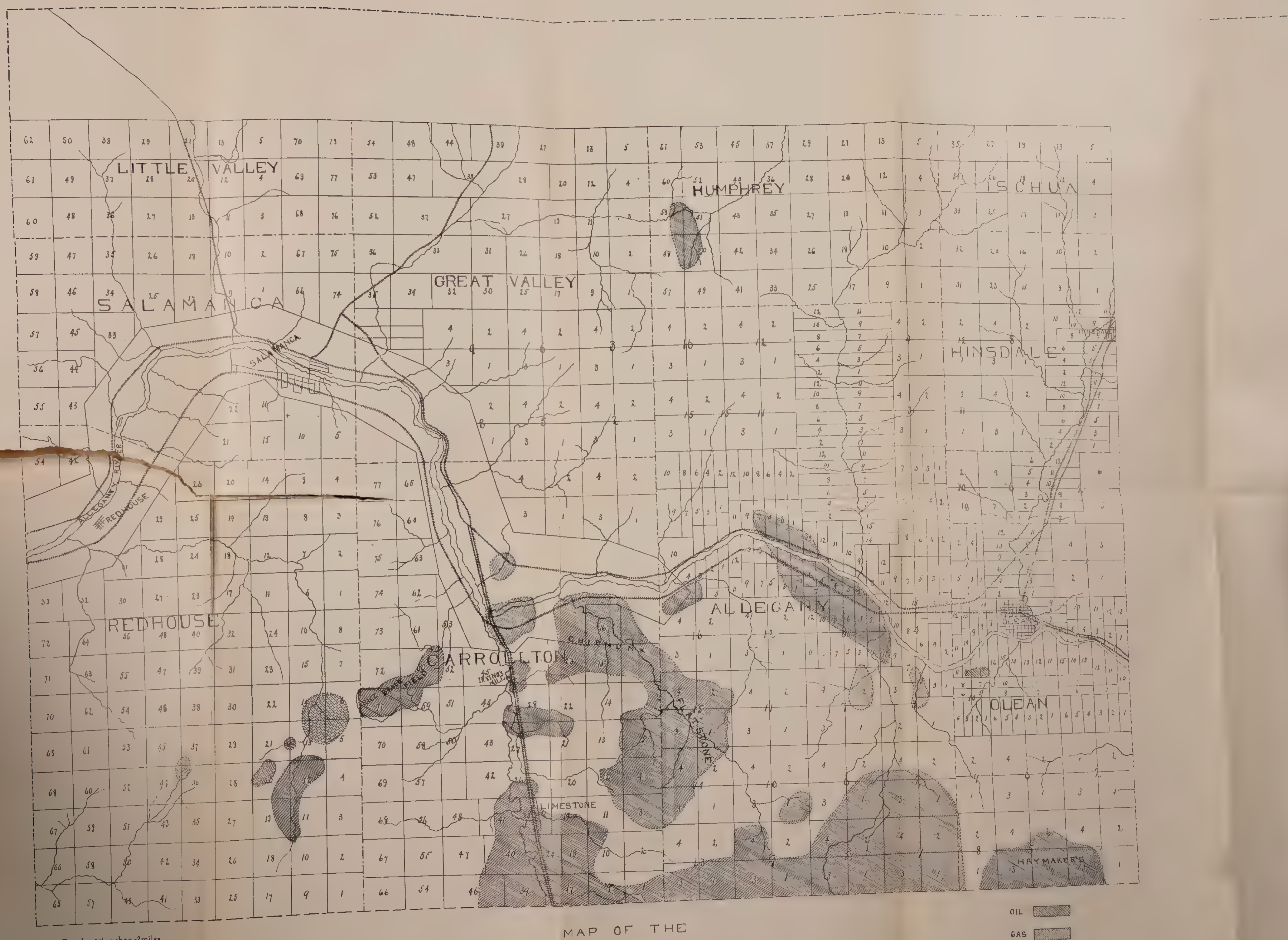
Conclusion

The limitations of time and appropriation for this investigation have prevented the extension of the work to the degree originally contemplated. The most important unfinished part is the correlation of the oil-producing sands of southern New York with the already recognized petroleum horizons in Pennsylvania.

Aside from the difficulty in obtaining correct records, referred to elsewhere, the main obstacle to this correlation lies in the absence of one or more well known horizons of reference from which measurements can be made. For illustration, there is in southern Cattaraugus co., no rock so easily recognized as are the Corniferous and Niagara limestones which furnish such reliable guides to the well-borer and geologist in northern and central New York.

Regarding the conglomerates and coarse sands which have served the purpose of reference in this region, there is still much confusion and in some localities at least, their identity is yet in question. As a consequence the measurements made from an uncertain horizon are in themselves uncertain and unreliable. The aneroid has not in my hands proved sufficiently accurate to warrant me in deciding that a doubtful outcrop was Olean or Subolean, specially in a region where, as in the case north of Bradford, flexures are known to exist.

It appears to me, therefore, that this work needs for its successful completion, 1) a careful study of the surface geology of Cattaraugus and Chautauqua counties for the purpose of mapping the outcrops of the several conglomerates; and 2) the accurate determination, by level, of the altitude of each conglomerate at several points. This investigation would require a month or more of field work, after which the solution of the problem would be comparatively simple. Incidentally light would be thrown upon the question of whether the sands are merely local lenticular deposits or widespread in extent.



Scale, 1¼ inches = 2 miles

MAP OF THE

CATTARAUGUS OIL AND GAS DISTRICT

CATTARAUGUS COUNTY, N.Y.

1898

Map

The accompanying map shows the present extent of the oil-pools of Cattaraugus co. in which the product has been found in commercial quantities. In the case of the Chipmunk pool the same oil-producing sands will undoubtedly be found, in the future, to extend much beyond the southern and eastern limits laid down upon the map, and may be found to include a part, at least, of the Rice Brook field. It has been my purpose however to avoid speculation and to include only such facts as are known to date.

I wish to acknowledge my indebtedness to Mr John Greenwood of Limestone, N. Y., whose intimate knowledge of the oil industry and of oil territory has been freely placed at my disposal while constructing the accompanying map.

Respectfully submitted

IRVING P. BISHOP

CLASSIFICATION AND DISTRIBUTION OF THE HAMILTON AND CHEMUNG SERIES OF CENTRAL AND EASTERN NEW YORK

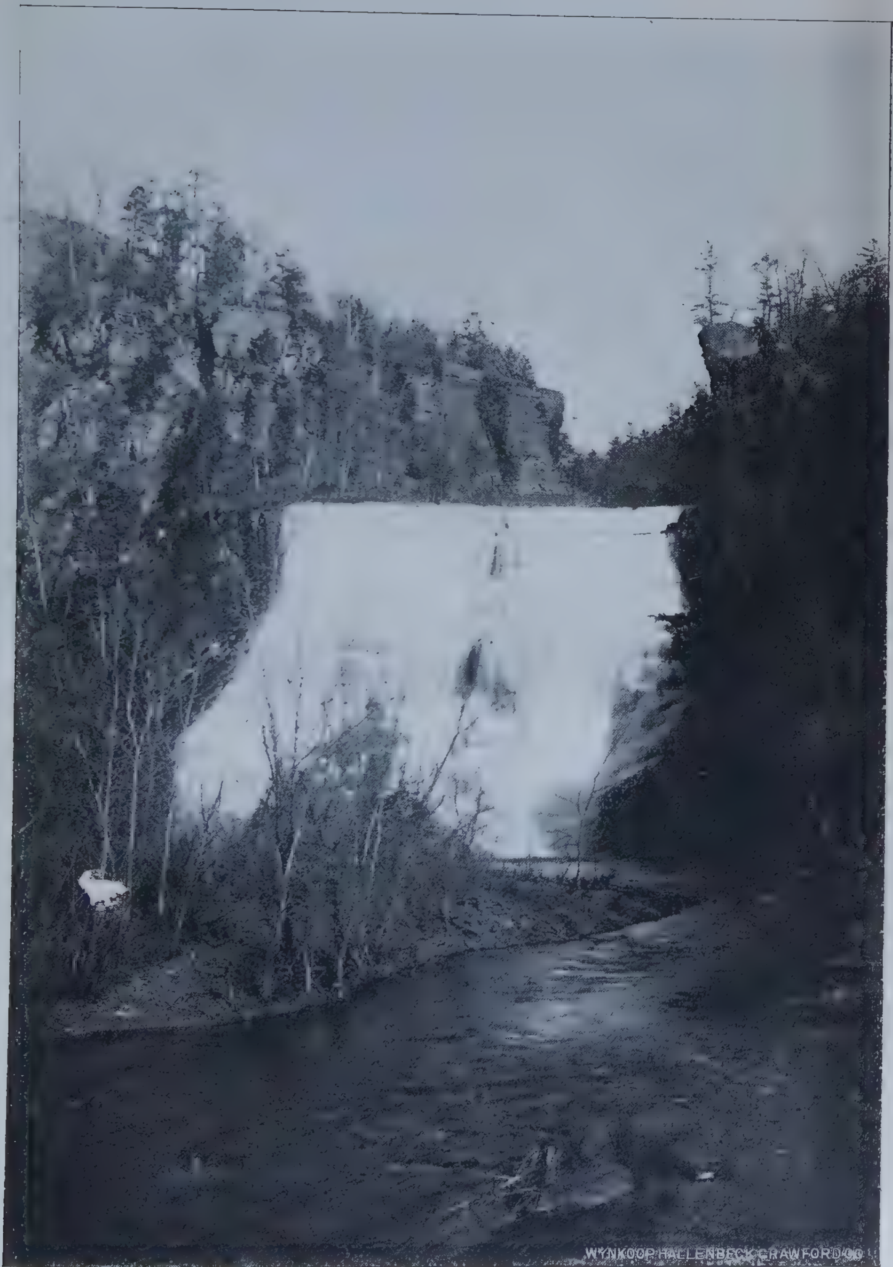
PART 2

CHARLES S. PROSSER

CONTENTS


MONTGOMERY
SCHENECTADY
ALBANY
GREENE
ULSTER
DELAWARE
SULLIVAN
ORANGE
PIKE
KINGSTON
CATSKILL
HUNTER
JEFFERSON
ROSEBOOM
DECATUR
WESTFORD
CHARLESTON
COLCHESTER
MARBLETOWN
SHAWANGUNK
NEW BALTIMORE
74°30'
74°00'
75°00'
42°30'
42°00'
41°30'
THE DISTRIBUTION OF THE
MIDDLE AND UPPER
DEVONIAN ROCKS
IN CENTRAL-EASTERN
NEW YORK
BY
CHARLES S. PROSSER
1898
LEGEND
CATSKILL AND ONEONTA
ITHACA AND SHERBURNE
HAMILTON

Plate 1



Lower Ithaca in Ithaca fall.

INTRODUCTION

In the summer of 1895 the formations of the Hamilton and Chemung series were studied in the field from the Chenango valley region eastward to the southern part of Albany and the northern part of Greene counties. The geology of this region from the Chenango valley to the eastern part of Otsego co. is described by the writer in the 15th *Annual report of the state geologist.*[a] This report was accompanied by a geologic map giving the boundaries of the Hamilton formation and of the Sherburne and Ithaca formations mapped together for Chenango, Otsego, Schoharie and Albany counties.

During the summer of 1897 field work was resumed in eastern New York and the formations of these series were studied and mapped from the southern part of Schoharie and Albany counties across Greene, Ulster, Sullivan and Orange counties to the New York-Pennsylvania state line along the Delaware river. The Chemung formation also was studied from the Susquehanna valley eastward across Delaware co. till its rocks merge into the red and gray sandstones and shales of the Catskill mountain region which are generally called the Catskill formation.

The present report will begin with the Susquehanna valley where part 1 closed, and will describe the formations from that valley to the Delaware river. The continuation of the areal distribution of the formations represented on the geologic map in part 1 is shown on the geologic map accompanying this report.

SUSQUEHANNA VALLEY SECTION

The Susquehanna river forms the outlet of Otsego lake near the central part of Otsego co., and its course is only slightly west of south till the southern line of the county is reached near which it receives Schenevus creek and the Charlotte river from the east. Then its direction is southwest across the southern part of Otsego co., between Otsego and Delaware counties and across the southeastern part of Chenango co., when it turns nearly southerly and crosses the eastern part of Broome co. into Pennsylvania. The Hamilton and Sherburne formations as exposed along the upper course of this river have already been described.[b]

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a P. 82–222.

b 18th an. report N. Y. state geologist, p. 198–204

Oneonta

Oneonta is one of the southern townships of Otsego co., to the north of which are the townships of Milford and Laurens, the geology of which was described in part 1 of this report; to the west is Otego township and on the south are the townships of Franklin and Davenport in Delaware co. The Susquehanna river crosses the southern central part of the township from nearly east to west and is lined by steep hills on both the northern and southern sides. The northern line is broken by the Emmons, Oneonta and Otego creeks; but the steep line to the south of the Susquehanna and Charlotte rivers is unbroken save by small brooks.

The Ithaca formation. In the first part of this report the bluish shales containing a few fossils which occur along the river road about one half mile north of Colliersville in the southern part of Milford township were described. These rocks were referred, with some hesitation, to the Sherburne formation and probably belong near its top. On the high hill to the east of the river and northeast of South Milford are exposures of the Sherburne sandstones.[a]

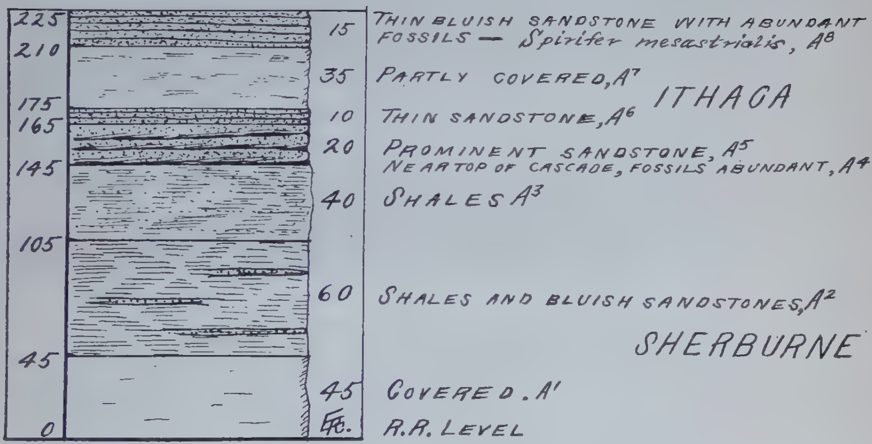
XXIII A^2. The next locality studied was a glen, known as Collier's gulf, less than one mile southwest of Colliersville in the southern part of Milford township. From the railroad level to the base of the lowest rocks exposed in the brook is about 45 feet, succeeding which are 60 feet of shales and thin bluish sandstones below the highway. The rocks contain scarcely any fossils and are referred to the Sherburne formation.

XXIII A^3. In the glen above the highway bridge for some 40 feet the rocks are shales in which *Chonetes* and *Spirifer mucronatus* (Con.) Bill. are common. These shales contain the lower fauna of the Ithaca group as it occurs in the Chenango and Unadilla valleys and this zone is referred to the base of that formation. The complete fauna is:

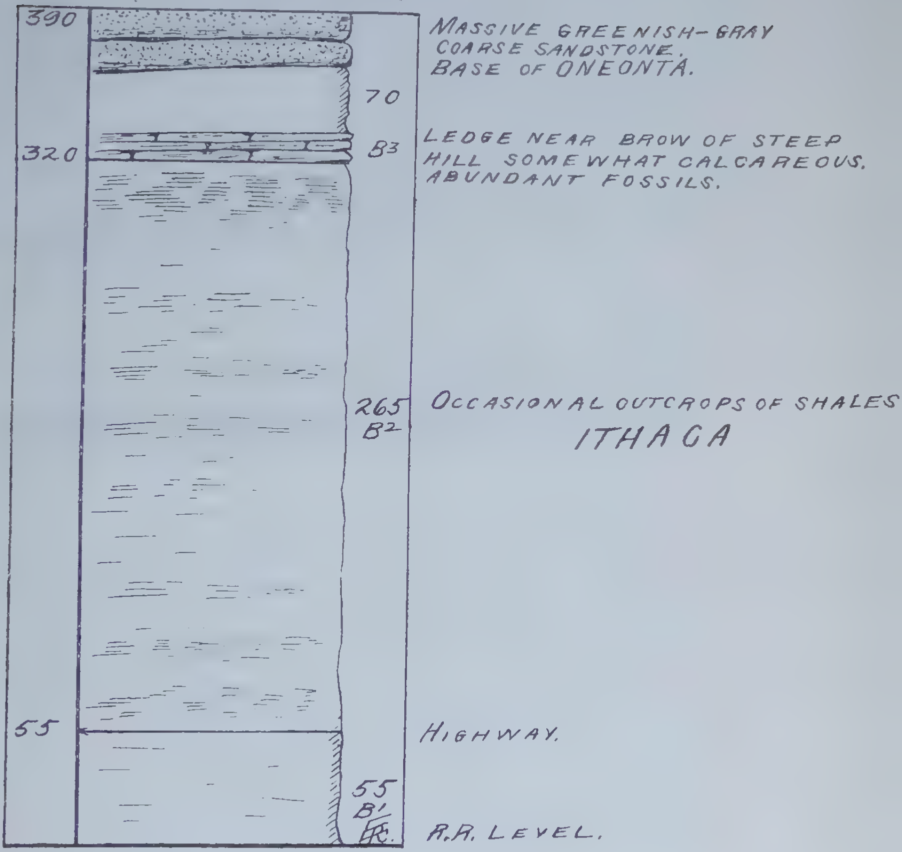
1	*Chonetes scitula* Hall	(c)
2	*C. setigera* Hall	(c)
3	*Spirifer mucronatus* (Con.) Bill.	(c)

a 15th an. rep't N. Y. state geologist. p. 202

No. 23. A. SECTION AT COLLIERSVILLE



No. 23, B SECTION
ON
EMMON'S FARM
3 MI. E. OF ONEONTA.



4 *Palaeoneilo emarginata* (Con.) Hall (rr)

5 *Leptodesma rogersi* Hall (rr)

6 *L.* sp. (rr)

Large specimen.

7 *Lunulicardium ornatum* Hall (?) (rr)

Badly broken.

8 *Coleolus tenuicinctum* Hall (rr)

XXIII A^4. Near the top of the cascade and higher in the glen are thin sandstones. In a layer of the shales near the top of the highest fall, fossils are more abundant, specially *Spirifer mesacostalis* Hall (?) which perhaps should be referred to *S. mucronatus* (Con.) Bill. var. *posterus* Hall and Clarke. This species is common. The other species found in this zone are *Chonetes setigera* Hall which is abundant, and *Chonetes scitula* Hall which is very rare.

XXIII A^5. Above the shales of A^4 near the top of the cascade there are from 15 to 20 feet of sandstones which make a prominent sandstone zone, some of the layers being quite coarse grained and fairly thick bedded. In the upper part of the zone *Spirifer mesastrialis* Hall and *Actinopteria boydi* (Con.) Hall are common; while *Spirifer mesacostalis* Hall (?) and *Tropidoleptus carinatus* (Con.) Hall occur sparingly.

XXIII A^6. 10 feet higher the rocks change to thinner sandstones and coarse arenaceous shales. A layer in this zone contains large numbers of specimens of *Spirifer mesacostalis* Hall (?) and *Tropidoleptus carinatus* (Con.) Hall. The fauna is as follows:

1 *Spirifer mesacostalis* Hall (?) (a)

Some specimens resemble *S. mucronatus* (Con.) Bill., but most of them agree better with this species.

2 *Spirifer mesastrialis* Hall (c)

3 *Tropidoleptus carinatus* (Con.) Hall (a)

4 *Chonetes setigera* Hall (r)

5 *Microdon (Cypricardella) gregarius* Hall (?) (rr)

Broken and imperfect specimen.

XXIII A^8. For about 35 feet above the conspicuous layer of fossils in zone A^6 the rocks are partly covered along the glen and

then 15 feet of thin bluish sandstones occur. Some of the layers are very fossiliferous and being strongly calcareous form a sort of firestone. The number of species is small, *Spirifer mesastrialis* Hall being the most abundant forms a large part of the thin layers of firestone. This zone very strongly resembles some of the calcareous layers near the middle of the Ithaca formation at Ithaca, New York. The top of this zone 225 feet above the level of the railroad is at the head of the glen, above which the rocks are mostly concealed by the soil and drift. The following species were collected in a few moments:

1	*Spirifer mesastrialis* Hall	(c)
2	*S. mesacostalis* Hall (?)	(c)
3	*Chonetes setigera* Hall	(rr)
4	*Tropidoleptus carinatus* (Con.) Hall	(rr)

In the search for fossils in the zones of this section but little time was spent and more exhaustive collecting would undoubtedly increase the number of species for each zone. It is considered, however, that these lists when taken into consideration with the stratigraphy of the southern part of Milford township show conclusively that at least the upper 80 feet of the section belong in the Ithaca formation, while the writer would refer the upper 120 feet to that formation and leave the lower 105 feet in the Sherburne formation.

XXIII B^3. Three miles east of Oneonta in the eastern part of Oneonta township is the "old Emmons farm" now owned by M. L. Swartz. At this locality is a steep hill and the base of the section is at railroad level about one half mile above Emmons station. The highway is some 55 feet above the railroad level and then for 265 feet the rocks forming the steep part of the hill are largely covered and only an occasional outcrop of shale is visible. Then ledges occur forming a conspicuous terrace along the side of the hill which seems to be its brow when viewed from the highway. One layer is hard and somewhat calcareous containing some pebbles and plenty of fossils specially *Camarotoechia*. These rocks contain the fauna of the Ithaca formation, as will be

seen from the following list of species obtained as a result of a few minutes' collecting from near the top of the section:

1	*Camarotoechia eximia* (Hall) H. & C.	(a)
2	*C. stevensi* (Hall) H. & C.	(c)
3	*Spirifer mesastrialis* Hall	(rr)
4	*Chonetes setigera* Hall	(r)
5	*C. scitula* Hall	(rr)
6	*Paracyclas lirata* (Con.) Hall	(r)
7	*Palaeoneilo maxima* (Con.) Hall	(r)
8	*Palaeoneilo* cf. *muta* Hall	(r)
9	*Sphenotus* cf. *contractus* Hall Poorly preserved.	(rr)
10	*Goniophora* sp.	(rr)
11	*Leptodesma rogersi* Hall (?)	(r)
12	*Nucula corbuliformis* Hall (?)	(rr)
13	*Tentaculites* sp. All very poorly preserved.	(c)

XXIII B[4]. 70 feet higher is the base of a massive, greenish gray coarse grained sandstone forming heavy ledges. On the surface the massive layers tend to separate into thinner ones but at a little distance from the surface these are firmly united forming massive strata. There are also layers which are conspicuously crossbedded. This zone has clearly all the lithologic characters of the massive sandstones of the Oneonta formation and represents its base on this hill. It will be clearly shown later in this report that these sandstones are not found at the same geologic horizon from the Chenango valley to Albany co.; but appear at a lower horizon as the formation is followed eastward. It is probable that the lowest of these heavy greenish gray sandstones as exposed at the various localities along the Susquehanna valley do not all represent exactly the same geologic horizon, but they form an easily recognized dividing line and have been regarded as constituting the base of the Oneonta sandstone in this valley. In fact it is doubtful if any line can be found between the Ithaca and Oneonta formations that can be followed exactly for a considerable distance. The lowest red shales and sandstones which have been used by some writers for the line of division between

the Ithaca and Oneonta formations are no more reliable than the massive greenish gray sandstones, for they also appear at lower and lower horizons as the Chemung series is followed eastward. It is evident, however, that in the vicinity of Oneonta, Vanuxem, who named the formation, referred these lowest massive greenish gray sandstones to it, for he mentions their crossbedded structure and gives as an example the ledges near the top of the hill below Oneonta,[a] which is the continuation, down the river, of the zone just described.

XXIII C^1. Along the highway that turns up the valley of the brook to the north of the river road about one and a half miles northeast of Oneonta are exposures of argillaceous and very thin sandstones. Some of the shales are greatly iron-stained. Toward the top of the hill which is covered by the Oneonta formation the rocks are largely hidden by the drift. The shales of C^1 along the highway are quite fossiliferous and belong in the Ithaca formation. The list is:

1 *Spirifer mesastrialis* Hall	(c)
2 *S. mesacostalis* Hall	(a)
3 *S. mucronatus* (Con.) Bill.	(r)
4 *Tropidoleptus carinatus* (Con.) Hall	(rr)
5 *Chonetes scitula* Hall	(r)
6 *Camarotoechia eximia* (Hall) H. & C.	(c)
7 *Cyrtina hamiltonensis* Hall	(rr)
8 *Leda diversa* Hall	(r)
9 *Paracyclas lirata* (Con.) Hall	(rr)
10 *Nucula* cf. *bellistriata* (Con.) Hall Small and poorly preserved.	(c)
11 *Palaeoneilo* cf. *muta* Hall	(rr)
12 *Nuculites cuneiformis* Con.	(rr)
13 *Modiomorpha* cf. *subalata* (Con.) Hall var. *chemungensis* Hall This is a more elongated specimen than any figured and in this respect agrees with other specimens seen in the Ithaca formation in the eastern counties.	(rr)
14 *Goniophora carinata* (Con.) Hall	(rr)
15 *Pleurotomaria sulcomarginata* Con.	(rr)

[a] Geology of New York. 1842, pt 3, p. 187.

XXIII D². To the northwest of Oneonta and north of Chestnut st. is a high hill known as Powell's hill, the summit of which is over 500 feet above the level of the Delaware and Hudson railroad. Below Chestnut st. at the foot of this hill, about three fourths of a mile west of the center of the city is a stone quarry known as the Anthony White quarry which was formerly worked considerably for building stone. The base of the quarry is about 10 feet above the railroad and its wall was formerly 16 feet high. The rocks containing fossils in abundance consist of bluish sandstones alternating with coarse shales. When the writer visited the quarry for the first time it had not been culled and a fine collection of fossils was secured for Cornell university. Three subsequent visits have been made which were not as successful as the first. This was due in part to lack of active quarrying and further to the fact that several geologists had visited the place for the purpose of making collections. As far as I am aware the complete list of fossils collected at the time of my first visit has never been published, but in the summer of 1895 the following species were collected:

1 *Spirifer mesastrialis* Hall (r)
2 *S. mucronatus* (Con.) Bill. (c)
3 *Tropidoleptus carinatus* (Con.) Hall (c)
4 *Chonetes scitula* Hall (r)
5 *C. setigera* Hall (a)
6 *C. lepida* Hall (?) (r)
The shape and number of striae agree with this species.
7 *Camarotoechia eximia* (Hall) H. & C. (c)
8 *Strophalosia* cf. *truncata* (Hall) Beecher (rr)
9 *Nucula bellistriata* (Con.) Hall var. (a)
The specimens have same shape though smaller than this species; but are marked with quite heavy lines of growth. This, however, is shown in fig. 7, pl. 46, *Paleontology of N. Y.*, v. 5, pt 1, Lamellibranchiata 2.
10 *Paracyclas lirata* (Con.) Hall (c)
11 *Palaeoneilo maxima* (Con.) Hall (r)
12 *Microdon* (*Cypricardella*) *tenuistriatus* Hall (r)
13 *Orthonota parvula* Hall (rr)

14 *Orthonota undulata* Con.
15 *Tellinopsis subemarginata* (Con.) Hall (rr)
16 *Modiomorpha mytiloides* (Con.) Hall (rr)
17 *M. concentrica* (Con.) Hall
18 *Leptodesma rogersi* Hall (r)
19 *Liopteria dekayi* Hall (rr)
20 *Glyptodesma erectum* (Con.) Hall (rr)
21 *Coleolus tenuicinctum* Hall (c)
22 *Tentaculites attenuatus* Hall (?) (r)
23 *Pleurotomaria sulcomarginata* Con. (c)
24 *Microdon (Cypricardella) bellistriata* (Con.) Hall
25 *M. (Cypricardella) gregarius* Hall
26 *Grammysia magna* Hall
27 *G. nodocostata* Hall
28 *Cimitaria recurva* (Con.) Hall (?)
29 *Goniophora carinata* (Con.) Hall
30 *Homalonotus dekayi* (Green) Emm.
31 *Nuculites triqueter* Con.
32 *Rhodea pinnata* Dn. (?)

The majority of the 32 species in the above list occur in the Hamilton formation, but the presence of *Spirifer mesastrialis* Hall and a few other species shows that this fauna belongs in the Ithaca formation of eastern New York. The geological range of 20 of these species was discussed by the writer a few years ago[a] and it hardly seems necessary to go over that argument again.

The rocks of this zone with some of their fossils were briefly described by Conrad in 1841, who proposed the name Oneonta group for the formation.[b] In his report Conrad named and described the following species: *Nuculites cuneiformis*, *N. maxima* (now *Palaeoncilo maxima* (Con.) Hall), and *Cypricardites carinata* (now *Goniophora carinata* (Con.) Hall), from this formation at Oneonta. This name was proposed two years later than that of the Ithaca group by Prof. Hall and apparently was not considered in the final reports of the New York survey. Vanuxem

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[a] Am. jour. science. 1893, 46:227.
[b] 5th an. rep't paleontology of N. Y. (Assembly doc. no. 150, 1841) p. 81.

referred to the formation in several places in his final report, but without mentioning Conrad's name, and in describing this hill referred the rocks at its base, correctly, to the Ithaca group. He states that the rocks of the Catskill group or Oneonta sandstones of Vanuxem "occupy the highest part of the face of the hill, the base of which is composed of rocks which I [Vanuxem] have supposed to belong to the Ithaca group."[a] Again, the term Oneonta as the name for a geological formation was already in use, for Vanuxem in 1840 proposed the name "*Montrose sandstone* or sandstone of Oneonta"[b] for the massive gray and red sandstones and shales that cover the high ground in the vicinity of Oneonta. Later studies have proved that the rocks in the vicinity of Montrose, Pa., belong in a later formation—the Catskill—than the higher sandstones about Oneonta, consequently the name Oneonta sandstone has been retained for this formation. Some years ago the writer called attention to this double use of Oneonta for a formation name and explained their difference in stratigraphic position[c].

XXIII D^4. Above Chestnut st. and about 29 feet above the top of the White quarry are fine, blue argillaceous shales which weather to a greenish color and break into very fine pieces. About 11 feet of these shales were formerly exposed but recent building has greatly obscured the outcrop. These shales are somewhat fossiliferous although but few species were ever collected in this zone. The list is as follows:

1	*Tropidoleptus carinatus* (Con.) Hall	(rr)
2	*Spirifer mesastrialis* Hall	(c)
3	*Camarotoechia eximia* (Hall) H. & C.	(r)
4	*Strophalosia* sp.	(rr)
5	*Chonetes* sp.	(rr)
6	*Nucula bellistriata* (Con.) Hall var.	(c)
7	*Paracyclas lirata* (Con.) Hall	(rr)
8	Crinoid segments	(rr)

a Geology of New York. 1842. pt 3, p. 192.
b 4th an. rep't third district (assembly document no. 50, 1840) p. 381.
c Proc. American ass'n adv. science, 1887. 36:210.

XXIII D^6. After about 34 feet of covered rocks an artificial exposure of greenish argillaceous shales was shown in an excavation for a cellar. These shales are fossiliferous, the following species having been obtained:

1	*Rhynchonella* sp.	(rr)
2	*Paracyclas lirata* (Con.) Hall	(a)
3	*Nuculites cuneiformis* Con.	(rr)
4	*Palaeoneilo maxima* (Con.) Hall	(rr)
5	*Grammysia* sp.	(rr)
6	*Tentaculites* sp.	(rr)
7	*Coleolus* sp.	(rr)

XXIII D^7. For 99 feet above the greenish shales of D^6 the rocks are mainly covered; but there are loose, angular slabs of arenaceous shales to thin sandstones on the surface that apparently came from this part of the hill. These pieces are somewhat fossiliferous, furnishing the following list:

1	*Spirifer mesastrialis* Hall	(rr)
2	*Camarotoechia eximia* (Hall) H. & C.	(r)
3	*Paracyclas lirata* (Con.) Hall	(rr)
4	*Palaeoneilo maxima* (Con.) Hall (?)	(rr)
5	*Nuculites oblongatus* Con. (?)	(rr)
6	*Orthoceras* sp.	(rr)
7	*Tentaculites* sp.	(rr)
8	Crinoid stems	(r)

XXIII D^8. At an elevation 199 feet above the railroad is an exposure of 10 feet of rocks. At the base of the ledge is a sandstone which splits into thin layers and contains an occasional fossil, as *Camarotoechia eximia* (Hall) H. & C. (?) and a large lamellibranch shell. Succeeding the thin sandstones are quite argillaceous shales which are also fossiliferous and, above the shales, sandstones more massive than those at the bottom of the ledge. In addition to those mentioned above, the ledge furnished the following species:

1	*Tropidoleptus carinatus* (Con.) Hall	(rr)
2	*Spirifer* sp.	(r)

3 *Nuculites oblongatus* Con. (rr)
4 *Palaeoneilo* sp. (rr)
5 *Tentaculites* sp. (rr)
6 A small Gastropod (rr)

XXIII D^{10}. The slope of the hill is then covered for about 189 feet and overgrown with underbrush when the base of the conspicuous rocks known as the "Oneonta ledge" is reached at 398 feet above the railroad. This is an interrupted and broken ledge varying in thickness from 10 to 30 feet or more, composed of coarse grained greenish gray sandstone that forms massive layers. Succeeding this is a covered slope of 64 feet when a smaller ledge—D^{12} of the section—is reached at an elevation of 492 feet above the railroad. At the base is a stratum of coarse gray sandstone capped by red sandstone. The summit of the hill is somewhat higher but there are no further outcrops of rocks. The rocks composing zones D^{10} and D^{12} are typical exposures of the Oneonta formation. The base of the formation is undoubtedly considerably lower and concealed by the deposit of drift, for on the Emmons farm about four miles east of Powell hill the base of the Oneonta sandstone is 390 feet above the railroad level and on the south side of the Susquehanna river opposite Oneonta it is about 265 feet above the level of the Oneonta railroad station.

SECTION OF POWELL HILL WEST OF ONEONTA

XXIII D

492′		D^{12}	Red sandstone near top of hill
	64′	D^{11}	Covered
428′			
	30′	D^{10}	Heavy ledge of greenish gray sandstone "The rocks" *Oneonta*
398′			
	189′	D^{9}	Covered
209′			
	10′	D^{8}	Bluish sandstone and shales *Ithaca*
199′			
	99′	D^{7}	Mostly covered. Loose specimens with fossils
100′		D^{6}	Greenish shales with fossils
	34′	D^{5}	Covered
66′			
	11′	D^{4}	Fine blue shales weathering greenish
55′			
	29′	D^{3}	Covered Chestnut street
26′			
	16′	D^{2}	White quarry. Blue sandstone and shale *Ithaca*
10′			
	10′	D^{1}	Covered
0′			R. R. level

In estimating the thickness of the rocks in the above section I am indebted to Prof. Henry S. Williams who has kindly loaned me notes made by me some years ago when at work on the U. S. geological survey under his direction. These readings have been compared with those taken during the progress of the field work upon which this report is based, which on account of storms were not as satisfactory as desired. The same acknowledgment should be made in reference to the sections described later, north of Otego and Sidney.

The red and gray sandstones forming the "Oneonta ledge" near the top of Powell hill, northwest of Oneonta, are important in the history of the nomenclature of the New York formations, since they are probably the typical outcrop to which Vanuxem in 1840 applied the name "sandstone of Oneonta" describing the formation as consisting "of many veins of gray sandstone, and sometimes of red sandstone; when weathered it exhibits a peculiar structure, to all appearance owing to the manner in which it was deposited from water; in this rock we often find the remains of terrestrial plants, and sometimes they are thrown together in such numbers as to form a thin mass of coal, extending for a few feet, but only an inch or more in thickness; this rock is found in Otsego, Chenango and Broome counties."[a] While in his final report in describing the localities where the crossbedded structure of the Catskill group[b] is shown in the most marked manner he cites "the hillside, near the top, below Oneonta."[c] As already stated and shown on the section, the writer refers the fossiliferous rocks in the lower part of Powell hill, at least to the top of D^8, 209 feet above the railroad, to the Ithaca formation. Many different opinions have been expressed in reference to the correlation of these fossiliferous deposits and it may be of interest to recall some of the more important ones.

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a 4th an. rep't third district (assembly document no. 50, 1840) p. 381.

b As already explained in his final report Vanuxem referred the Oneonta sandstone to the Catskill formation; a classification that is now abandoned.

c Geology of New York. 1842. pt 3, p. 187.

In 1841 Conrad named them the Oneonta group,[a] while in the following year Vanuxem referred them correctly to the Ithaca group.[b] In 1885 Prof. Hall published the following classification for the Devonian system of Otsego, Delaware and Chenango counties:

'Catskill group
Chemung group
Oneonta { Portage group / Hamilton (upper)
Hamilton group
Corniferous limestone
Oriskany sandstone.'[c]

The author states that the Oneonta sandstone "comes in at about the close of the Hamilton period, or more properly may be regarded as the result of changes which terminated the conditions of the Hamilton group."[d] In the list of localities following the description of species, *Goniophora carinata* (Con.) Hall from Oneonta,[e] *Nuculites cuneiformis* Con., at Oneonta,[f] and *Phthonia nodicostata* Hall near Oneonta[g] are referred to the Hamilton group.

In 1886 Prof. H. S. Williams showed that the fossiliferous rocks at Oneonta belong stratigraphically above the horizon of the Genesee shale and he called them the *Paracyclas lirata* stage.[h]

Prosser in 1887 showed that between the fossiliferous rocks of Oneonta and the top of the Hamilton formation are the Sherburne flagstones of Vanuxem.[i]

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a 5th an. rep't paleontology of N. Y. (assembly doc. no. 150, 1841) p. 31.
b Geology of New York. 1842. pt 3, p. 192.
c Geol. surv., N. Y. Paleontology, 5, pt 1, Lamellibranchiata 2:518.
d Ibid, p. 517.
e Ibid, p. 302.
f Ibid, p. 326.
g Ibid, p. 474.
h Proc. American ass'n adv. science, 34:225, 233 and *see* §10 of the chart of Meridional sections of the Upper Devonian deposits of New York, Pennsylvania and Ohio.
i Proc. American ass'n adv. science, 34:210.

Darton in 1893 referred them to the Hamilton stating "The basal beds [of the Oneonta] are gray flags which merge into the Hamilton."[a]

And again that "The Chemung rocks to which Mather and others refer, lie below the Oneonta beds or about 1000 feet below the actual base of the Chemung horizon, and are Hamilton in position. Their fauna is meager and consists of species supposed by Vanuxem to be 'Chemung' [Ithaca] in central New York, but now known to be Hamilton."[b]

The same year, 1893, Prosser published a paper describing several characteristic sections of the upper Hamilton, Sherburne, and Ithaca formations in eastern New York accompanied by lists of fossils. One of these localities was the Anthony White quarry west of Oneonta from which a list of 20 species with their geologic range was given.[c] The paper concluded as follows: "It seems clear to the writer that the above lists of fossils with the statement of their stratigraphic position show that the fossiliferous zone underlying the Oneonta sandstone in Chenango and Otsego counties is not the top of the Hamilton but belongs in the Portage stage."[d] By the use of the word *stage* in the preceding sentence the writer intended to convey the idea that in his opinion this fossiliferous zone was synchronous with some part of the formation which on the Genesee river is called the Portage; or along the meridian of Cayuga lake is called the Lower Portage, Ithaca and Upper Portage but did not say with *which part* of that formation it was to be correlated.

On the *Geologic map of New York*, 1894, the rocks along the Susquehanna river valley above, and for some distance below Oneonta are referred to the upper part of the Hamilton formation.

XXIII F^2. East of the Powell hill section, flowing from the north through the central part of Oneonta is a stream known as

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a Am. jour. science, 3d ser., March, 1893, 45: 206.

b Ibid, p. 207. Also see Sec. B of fig. 2 on p. 205, where the Oneonta sandstone is represented diagrammatically as resting on the Hamilton formation at Oneonta.

c Ibid, Sep., 46: 326-29.

d Ibid, p. 230.

Silver creek. About 200 feet above the railroad level, along this stream is an exposure of bluish shale that breaks upon weathering into small, irregular pieces. These shales and those somewhat higher along the bank of the old "race way" are quite fossiliferous. The following species were collected:

1	*Spirifer mesastrialis* Hall	(r)
2	*S. mucronatus* (Con.) Bill.	(rr)
3	*Chonetes scitula* Hall	(a)
4	*Camarotoechia stevensi* (Hall) H. & C.	(r)
5	*Camarotoechia eximia* (Hall) H. & C.	(r)
6	*Paracyclas lirata* (Con.) Hall	(r)
7	*Microdon (Cypricardella) bellistriatus* (Con.) Hall Ithaca form.	(rr)
8	*Nuculites oblongatus* Con.	(rr)
9	*Nucula bellistriata* (Con.) Hall var.	(rr)
10	*Palaeoneilo maxima* (Con.) Hall	(rr)
11	*Leptodesma* sp.	(r)
12	*Pleurotomaria* sp.	(r)
13	*Bellerophon* sp.	(rr)
14	*Tentaculites* sp.	(rr)
15	Crinoid segments	(r)
16	*Strophalosia* sp.	(rr)
17	*Tellinopsis subemarginata* (Con.) Hall	(rr)
18	*Goniophora carinata* (Con.) Hall	(rr)
19	*Coleolus* sp.	(rr)
20	*Hyolithes* sp.	(rr)

XXIII F^3. Farther up the creek is a calcareous stratum two feet or more in thickness, merging into a sandstone below and a shale above. The calcareous part is very hard when freshly exposed but on weathering becomes brown and friable. The shale is very fossiliferous though the specimens are badly broken and the number of species is small.

XXIII F^4. From the limestone to the upper exposures, sandstones and shales alternate with lithologic characters similar to those in F^2. The combined thickness of the exposed rocks, F^2, F^3

and F^4 is 50 feet. The fossiliferous layers extend nearly to the highest exposures which are 200 feet or more above the White quarry. The following species were collected in this upper zone:

1 *Chonetes scitula* Hall (r)
2 *Camarotoechia* sp. (rr)
3 *Spirifer* sp. (rr)
4 *Palaeoneilo maxima* (Con.) Hall (rr)
5 *Nucula bellistriata* (Con.) Hall var. (rr)
6 (?) *Tellinopsis subemarginata* (Con.) Hall (rr)
7 *Coleolus* sp. (rr)

XXIII X^2. On the south side of the Susquehanna river, nearly opposite Oneonta, along the Delhi road and a small brook are exposures of the upper part of the Ithaca formation capped by the Oneonta sandstone. At an elevation of about 170 feet above the railroad level on the banks of the small stream are bluish shales alternating with thin sandstones. Some of the layers are slightly calcareous and contain some fossils, though the number of species is small as will be seen by the following list:

1 *Spirifer mesastrialis* Hall (c)
2 *S. mucronatus* (Con.) Bill. (c)
3 *Goniophora hamiltonensis* (Hall) Miller (?) (rr)
Poorly preserved.
4 *Edmondia* cf. *subovata* Hall (r)
These specimens resemble fig. 21, pl. 64, *Paleontology of New York*, v.5, pt 1, *Lamellibranchiata* 2, which came from the Ithaca group at Ithaca and was referred with doubt to this species.
5 *Homalonotus dekayi* (Green) Emm. (rr)

These rocks belong in the upper part of the Ithaca formation, which extends somewhat higher. For 80 feet above X^2 the rocks are mostly covered, when a coarse grained, greenish gray sandstone outcrops by the side of the highway, and in the field to the southwest is a small quarry. This stratum—X^4—is 250 feet by the barometer above the railroad level and in its lithologic and structural characters closely resembles the Oneonta sandstone,

and is regarded as forming the base of this formation in the steep hill along the southern side of the Susquehanna river opposite Oneonta. About 50 feet higher by the western side of the highway is a small quarry in the greenish gray sandstone capped by red shale. This shale is X^6 of the section and its base is 312 feet by the barometer above the railroad level. There is a marked dip at this locality of 2½° S, 10° W. The section may be represented diagrammatically as follows:

SECTION SOUTH OF ONEONTA

312′		X^6 Red shale *Oneonta* formation
	62′	X^5 Greenish gray ss. with some shale
250′		X^4 Greenish gray sandstone Base of *Oneonta* sandstone
	80′	X^3 Mostly covered Probably *Ithaca*
170′		X^2 Bluish shales with fossils *Ithaca* formation
	170′	X^1 Largely covered
0′		R. R. level Oneonta station

About one and one third miles west of the Delhi road the steep hill is crossed by the Franklin turnpike. Red sandstones and shales were first noticed along this road 245 feet below its summit, while at 180 feet below the summit is an exposure of 15 feet of red shale which has colored the road a bright red and has been quarried to some extent and used for red paint. The reds and grays alternate from this horizon to the summit of the road.

West Oneonta. XXIII E[1]. The western part of Oneonta township is crossed by the Otego creek and one of its western branches is Perry brook which flows through the small village of West Oneonta. About one fourth mile above West Oneonta is an old mill and along the banks of the creek below and above the mill are very fossiliferous, bluish, argillaceous shales. Loose in the brook are large slabs of sandstone containing numerous large and nicely preserved specimens of *Spirifer mesastrialis* Hall. The rocks along the creek show a decided dip to the southwest. The base of these shales is about 105 feet higher than the bridge over the Otego creek at West Oneonta, approximately 130 feet above the base of the Powell hill section at Oneonta, and three miles northwest of the base of that section. The fauna is:

1	*Spirifer mesastrialis* Hall	(c)
2	*S. mucronatus* (Con.) Bill.	(rr)
3	*S. mesacostalis* Hall (?)	(rr)
4	*Camarotoechia eximia* (Hall) H. & C.	(c)
5	*C. stevensi* (Hall) H. & C.	(c)
6	*Chonetes scitula* Hall	(r)
7	*C. setigera* Hall	(c)
8	*Orbiculoidea neglecta* (Hall) H. & C. (?)	(rr)
9	*Paracyclas lirata* (Con.) Hall	(a)
10	*Prothyris lanceolata* Hall	(rr)
11	*Microdon (Cypricardella) tenuistriatus* Hall	(rr)
12	*Palaeoneilo maxima* (Con.) Hall	(rr)
13	*Modiomorpha subalata* (Con.) Hall var. *chemungensis* Hall The large and elongate form found in the east.	(r)
14	*Modiomorpha* cf. *mytiloides* (Con.) Hall This is a small specimen resembling in some respects *M. alta* (Con.) Hall as fully as the above species.	(rr)
15	*Grammysia elliptica* Hall	(rr)
16	*G. nodocostata* Hall The impressions show nodose ridges near the umbo similar to figures of this species.	(rr)
17	*Grammysia constricta* Hall	(rr)
18	*Goniophora* sp.	(rr)

19	*Leptodesma rogersi* Hall	(c)
20	*Actinopteria theta* Hall (?)	(rr)
21	*Liopteria* sp.	(rr)
22	*Pleurotomaria sulcomarginata* Con.	(c)
23	*Bellerophon rudis* Hall (?)	(rr)
24	*Orthoceras* sp.	(rr)

It will be seen that the above fauna corresponds to that of the bluish shales in the vicinity of Oneonta and these rocks belong in the Ithaca formation, as well as those occurring by the roadside and along the stream till the upper part of the glen, which crosses the township line in the northeast corner of Otego township, is reached 230 feet above the base of the shales forming E^1.

Otego

To the west of Oneonta is Otego township, the southern part of which is in the Susquehanna river valley. The central part is crossed by the Otsdawa creek, which enters the Susquehanna river in the vicinity of Otego village, and in the northern and western parts and on the south side of the Susquehanna river are high hills. A large part of the township is covered by the Oneonta formation while the Ithaca formation extends along the Susquehanna river valley to the southwest of Otego village, and the high land in the western part of the township belongs in the Chemung formation.

Ithaca formation. LXXI C^1. In the eastern part of the township are exposures of rocks along Mill creek to the north of the river road about two and one half miles east of Otego. At the foot of the gorge are about eight feet of bluish shales which weather to a slightly greenish tint, and contain some concretions and a few fossils, mostly very imperfectly preserved.

LXXI C^2. Above the shales is a sandstone stratum two feet thick. This is succeeded by another two foot layer of very irregular structure which, in places, is composed almost entirely of concretions. Above are more sandstones, some of which are slightly calcareous and about 16 feet above the concretionary one is a strongly calcareous stratum. The sandstones are about 22 feet thick, above which are argillaceous shales containing fossils

capped by a sandstone which forms the top of the falls in the glen. The thickness of this entire zone is about 30 feet. From the different layers the following species were collected:

1	*Spirifer mesastrialis* Hall	(c)
2	*S. mesacostalis* Hall (?)	(c)
3	*Camarotoechia eximia* (Hall) H. & C.	(c)
4	*Paracyclas lirata* (Con.) Hall	(rr)
5	*Prothyris lanceolata* Hall	(rr)
6	*Modiomorpha concentrica* (Con.) Hall	(rr)
7	*Nuculites oblongatus* Con.	(r)
8	*N. cuneiformis* Con.	(rr)
9	*Microdon (Cypricardella) tenuistriatus* Hall	(rr)
10	*Coleolus* sp.	(rr)
11	Fish plates and teeth	(r)

LXXI C^3. From the top of the falls to the top of the cliff there are 50 feet of alternating shaly and thin sandstone layers. These rocks contain some fossils, though the number of specimens and species is smaller than in those of C^2. The species listed below were obtained:

1	*Tropidoleptus carinatus* (Con.) Hall	(r)
2	*Spirifer* sp.	(r)
3	*Camarotoechia* sp.	(rr)
4	*Paracyclas lirata* (Con.) Hall	(c)
5	*Nuculites oblongatus* Con. (?)	(rr)
6	*Actinopteria* sp.	(rr)
7	*Coleolus* sp.	(rr)
8	Crinoid segments	(c)

The top of these rocks is approximately 155 feet above railroad level to the east of Otego and the three zones belong in the Ithaca formation.

LXXI B^1. On the northern bank of the Susquehanna river about one mile east of Otego is a cliff of shales and sandstones some 20 feet in hight. The base reaches water level and for 10 feet is composed of bluish shales with thin, slightly calcareous, concretionary layers. Then quite a heavy sandstone stratum occurs with quite arenaceous shales and above this a sandstone stratum a foot or

more in thickness at the base of which are rounded concretions. From this sandstone to the top of the cliff shales are found. The middle of the cliff is on a level with the railroad track on the south side of the river. These rocks are quite fossiliferous and belong in the Ithaca formation. The species listed below were collected:

1	*Spirifer mesastrialis* Hall	(c)
2	*Camarotoechia eximia* (Hall) H. & C.	(c)
3	*Tropidoleptus carinatus* (Con.) Hall	(rr)
4.	*Strophalosia speciosa* (Hall) Beecher	(r)
5	*Paracyclas lirata* (Con.) Hall	(r)
6	*Palaeoneilo* sp.	(rr)
7	*Pleurotomaria* sp.	(rr)
8	*Orthoceras* sp.	(rr)
9	*Cladochonus* sp.	(rr)
10	Crinoid segments—large and small	(c)

LXXI A². Along Otsdawa creek at the narrows one mile north of Otego village is an interesting exposure because the passage from the top of the Ithaca formation into the Oneonta sandstone is clearly shown. The level of the creek at the highway crossing east of Otego on the river road is only about five feet lower than the railroad level but from this point to the next bridge across the creek on the north road where the top of the Ithaca formation is reached there is a rise of 51 feet. By the side of the creek at this bridge about three feet of shales are exposed which contain a few fossils but most of the specimens are poorly preserved and the fauna is meager. The list is as follows:

1	*Nuculites oblongatus* Con.	(c)
2	(?) *Modiomorpha* sp.	(r)
3	(?) *Leptodesma* sp.	(rr)
4	Crinoid segments—large size	(r)
5	Plant stems	(c)

Above these shales the rocks are covered for three feet, then there is a ledge of thin sandstone and shales two feet thick.

On the bank of the creek at this locality above the shale and sandstone the rocks are concealed for 10 feet; but a little farther

up the creek a two foot sandstone stratum shows. In the cliff above the covered portion are thin shaly layers of gray sandstone which soon become greenish gray and massive, and about 11 feet above their base is a mass of blue shale in the midst of the massive gray sandstone which is like a channel filling. The gray coarse grained sandstone continues for 37 feet when a stratum of red shale two feet thick is reached, on top of which is one foot of red sandstone and above this a one foot stratum of gray sandstone capped by drift. It is evident that the coarse gray sandstone with the red shale and sandstone above forms the basal part of the Oneonta formation. At the upper end of the short gorge, immediately above the third highway bridge is a small quarry in the greenish gray Oneonta sandstone not far below the red shale. At this place a block was found, evidently from the quarry, on which are three well preserved specimens of *Amnigenia catskillensis* (Van.) Hall. It will be remembered that the above rare fossil is the characteristic shell of the Oneonta formation to which it is supposed to be confined. This report mentions several new localities at which the shell was found and careful search would probably serve to increase the number.

On the hillside 125 feet above the top of the cliff in the above section is a broken sandstone ledge which varies from a few to 20 or more feet in thickness. At the base there is a gray sandstone followed by a red with gray sandstone again at the top of the ledge.

The section along Otsdawa creek may be tabulated as follows:

OTSDAWA CREEK SECTION

Elevation	Thickness	Description	Division
255′			
	20′	A⁷ Gray and red sandstone	
235′			
	125′	Concealed A⁶	
110′			
	1′	Gray sandstone	A⁵
109′			
	3′	Red shale and sandstone	
106′			
	37′	A⁴ Greenish gray sandstone *Oneonta*	
69′			
	10′	A³ Concealed	
59′			
	2′	Shales and sandstones	A² *Ithaca*
	3′	Covered	
	3′	Shales at second bridge	
51′			
	51′	A¹ Covered	
	. . . . . .	8′ Approximate R. R. level	
0′		Creek level at river road bridge	

A comparison of the elevation of the base of the Oneonta sandstone in the Emmons section with that of the Ostdawa affords the means for determining the amount of dip a mile between the two localities. The base of the Oneonta sandstone in the Emmons section is 390 feet above railroad level and in the Otsdawa section approximately 60 feet. The railroad level at Otego is approximately 73 feet lower than at Emmons which makes the Oneonta sandstone approximately 403 feet lower in the Ostdawa glen than in the Emmons section. The two stations are about 9.6 miles apart which would give a dip of 42 feet a mile to the southwest.

To the southwest of Otego the Oneonta sandstone soon runs down to the level of the highway and there are frequent exposures of red shale and sandstone, alternating with coarse grayish sandstone by the side of the highway between Otego and Wells Bridge in the southeastern corner of Unadilla township.

On the *Geologic Map of New York* the base of the Oneonta sandstone is represented at East Unadilla which is probably some three or four miles too far to the southwest. The dip would indicate that the base of the Oneonta sandstone reaches river level within a distance of less than two miles southwest of Otego.

Unadilla

This is the southwestern township of Otsego county, situated to the west of Otego and bounded respectively on the south and west by the Susquehanna and Unadilla rivers which come together at the southwestern corner of the township. The greater part of the township is covered by the Oneonta formation, the red and gray sandstones being well exposed along a number of the streams. In the Delaware and Hudson railroad cut above Unadilla village is an excellent exposure of the Oneonta greenish sandstone and red shales. The high ground in the northeastern part of the township is covered by the Chemung while the hill at the southwestern point forming the divide between the Unadilla and Susquehanna rivers is capped by the base of the Chemung.

LXXIV A^2. To the northwest of Sidney is the hill just mentioned which forms the angle between the two rivers near their confluence. There are a few exposures on the hillside which are important since they show that the lower part of the hill is in the Oneonta formation while the upper part belongs in the base of the Chemung.

On the road to the Secor quarry at an elevation of 95 feet above the Susquehanna river bridge and approximately the same elevation above railroad level is an outcrop of red, arenaceous shale and sandstone. This part of the hill is well covered by drift and there is only a small exposure of the rock.

LXXIV A^4. Above this outcrop at an elevation of 110 feet is a small quarry of building stone known as Secor's quarry in which 15 feet of rocks are exposed consisting of a grayish to olive sandstone with greenish to bluish argillaceous shale partings. The rock splits into rather rough layers some of which contain clay pebbles. Nothing but plant and crinoid stems were found in the debris of the quarry but in the adjacent portions of Delaware, Otsego and Chenango counties the first fauna of the Chemung stage consists largely of crinoid segments so that it seems reasonably safe to refer the rocks of this quarry to the base of the Chemung.

LXXIV A^6. Along the field road some 95 feet higher than the quarry are small ledges of bluish shale in which a few fossils were found, viz, *Spirifer mesacostalis* Hall, small form, common; *Tentaculites* sp.; and crinoid segments. These shales as their fauna clearly indicates are in the lower part of the Chemung formation. The summit of the hill is some 90 feet above the shales of A^6 and on its surface are loose, angular slabs, evidently from that vicinity, a few of which are calcareous—like a firestone—and composed largely of small crinoid segments and specimens of *Atrypa reticularis* (Lin.) Dal. In some of the slabs specimens of *Liorhynchus globuliformis* (Van.) Hall, *Atrypa reticularis* (Lin.) Dal., *Leptodesma* and *Tentaculites* sp. are found but most of them contain crinoid segments.

The section may be represented in the following diagrammatic manner:

SECTION OF HILL NORTHWEST OF SIDNEY

405′			
	90′	A^7	Covered to summit of hill
315′		A^6	Bluish shale
	95′	A^5	Covered
220′			
	15′	A^4	Secor's quarry. Sandstone and shale
205′			
	110′	A^3	Covered
95′		A^2	Red shale and sandstone
	95′	A^1	Covered
0′			River bridge and railroad level

The comparison of the section north of Sidney with that of the Otsdawa north of Otego furnishes a means of estimating the thickness of the Oneonta formation. The distance between the two sections is 12¼ miles; the Sidney station is 64 feet lower than the Otego while the base of the Oneonta formation on the Otsdawa creek is 60 feet above the railroad level. If we assume that the dip remains the same between Otego and Sidney as between

Emmons and Otego then there is a thickness of 485 feet of rocks from the bottom of the Oneonta formation to the red shales of A^2 in the section north of Sidney and a thickness of 595 feet from the bottom of the Oneonta to Secor's quarry. It is probable that the top of the Oneonta formation lies between the red shales and the base of the quarry indicating that the thickness of the formation is between 500 and 600 feet.

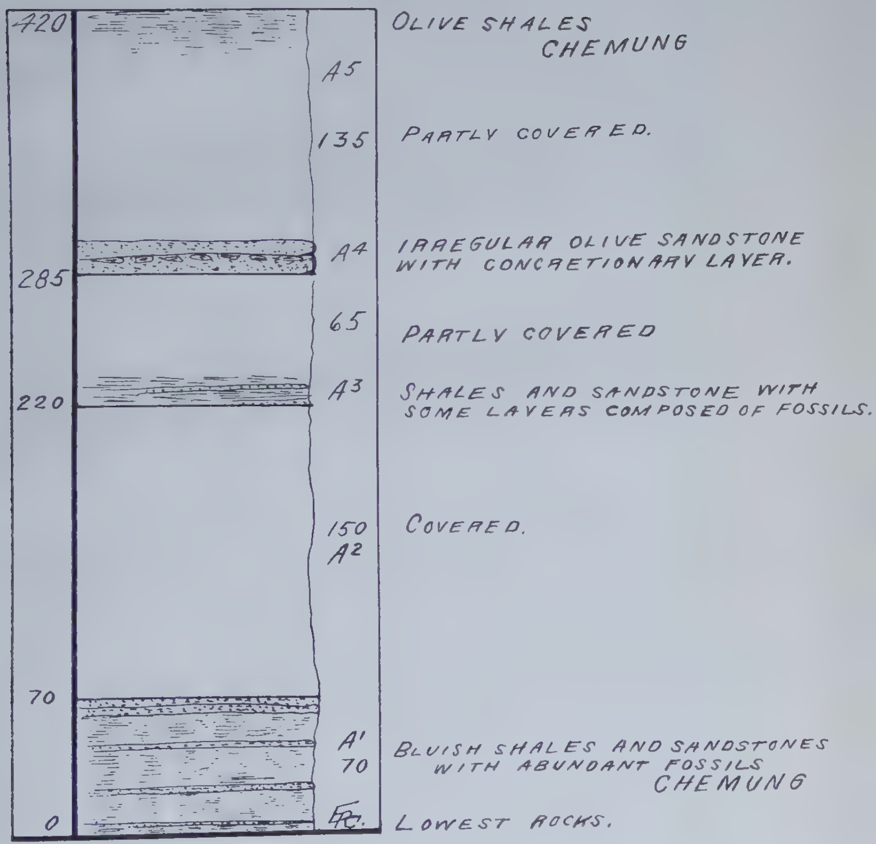
Bainbridge

The next township to the southwest in the Susquehanna river valley is Bainbridge in the southeastern part of Chenango county. The eastern half of the township is crossed diagonally by the river from the northeast to the southwest and the larger part of it is covered by rocks of the Chemung formation, the Oneonta formation occurring only along the valley of the Susquehanna river and its tributaries in the eastern part of the township.

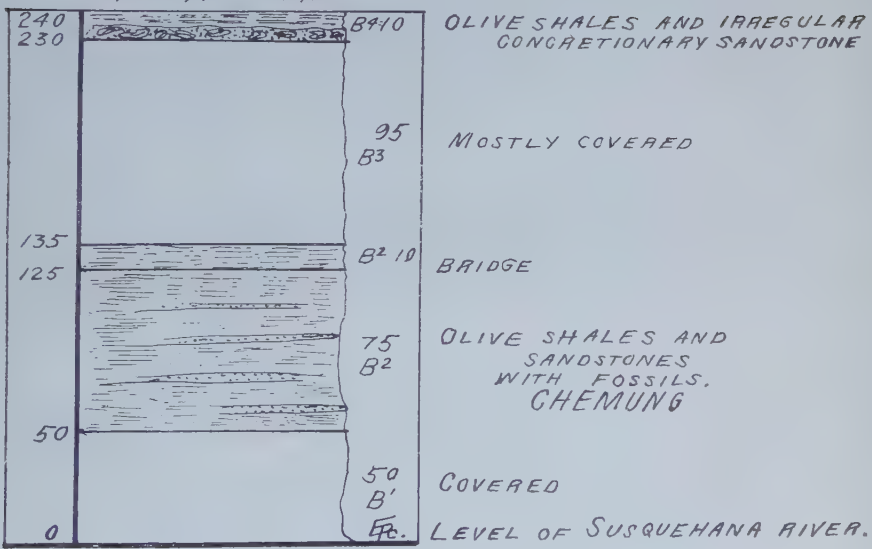
XXXIV A^1. In the northwestern part of Bainbridge village along the stream from the northwest is a small glen which is quite narrow and for some distance bounded by walls exposing 70 feet of rock, the base of which is about 80 feet above the level of the Park hotel in the central part of the village. The rocks consist mostly of bluish shales and thin sandstones with one or two irregular slightly concretionary strata. The shales are fairly fossiliferous, specially in certain layers, while in the sandstones a smaller number of fossils is found. There are frequently somewhat calcareous layers in which occur great numbers of crinoid segments. The lower shales contain numerous specimens of *Spirifer mucronatus* (Con.) Bill. var. *posterus* Hall & Clarke which occurs in all of the rocks of this zone. In the upper part of the glen are layers containing many specimens of *Liorhynchus globuliformis* (Van.) Hall; a smaller number of *Productella lachrymosa* (Con.) Hall and very large specimens of *Atrypa reticularis* (Linn.) Dal. The complete fauna of the zone follows:

1 *Atrypa reticularis* (Linn.) Dal. (a)
Broad specimens with coarse plications.

No. 34, A. SECTION AT BAINBRIDGE



No. 69, B. SECTION OF BUMP'S CREEK AT AFTON



2 *Spirifer mucronatus* (Con.) Bill. (aa)
var. *posterus* Hall & Clarke

Small and very mucronate. Apparently this species. Some of these specimens were examined by Dr Clarke who wrote of them as follows: "These specimens are more progressed towards *Sp. mesacostalis* [than the Ithaca fauna *Sp. mucronatus* var. *posterus*]; the internal septum is more pronounced and the median costa stronger. They impress one as distinctly more progressed toward the *mesacostalis* extreme. I have called them *posterus;* perhaps it would be nearer the truth if one should designate them as *posterus*+or *mesacostalis*—. I would not call them *mesacostalis* for the concept which that term embodies is a *mucronatus* with a well developed median costa and internal septum."

3 *Cyrtina hamiltonensis* Hall (rr)

4 *Schizophoria impressa* (Hall) H. & C.
=*S. striatula* (Schl.) Schuchert (r)

5 *Productella lachrymosa* (Con.) Hall (c)

6 *Liorhynchus globuliformis* (Van.) Hall (aa)

The specimens are flattened in the shale but I think they are the above species rather than *L. mesacostalis* Hall.

7 *Cryptonella eudora* Hall (?) (rr)

8 *Leptodesma* sp. (rr)

9 *Palaeoneilo brevis* Hall (?) (rr)

10 *Tentaculites spiculus* Hall (?) (a)

11 Crinoid segments and stems (c)

These rocks are, clearly, stratigraphically above the Oneonta formation and correspond with those of Greene township along the Chenango valley and as the writer stated in the early part of this report they may be regarded as representing the lower part of the Chemung formation.[a] However before this question can be settled authoritatively the rocks should be carefully studied and followed across the country from the Chenango valley to the southern part of Tompkins county. This fauna was called the *Liorhynchus globuliformis* stage by Prof. H. S. Williams who studied specimens from this glen and considered them to repre-

[a] 15th an. rep't N. Y. state geologist, p. 165.

sent a modified Hamilton fauna occurring below the base of the Chemung.[a]

XXXIV A^3. Farther up the brook, about one mile northwest of Bainbridge, a small branch enters it from the south along which are exposures of rocks. Ledges also occur along the highway a short distance farther northwest. These rocks are 150 feet higher than the top of the glen; but in general their lithologic characters are similar to those in the glen, though there are thicker layers which are strongly calcareous and composed largely of fossils, specially the small *Spirifer*. The following species were collected:

1	*Spirifer mucronatus* (Con.) Bill. (?) var. *posterus* H. & C.	(aa)
2	*S. mesastrialis* Hall	(r)
3	*Productella lachrymosa* (Con.) Hall	(r)
4	*Modiomorpha quadrula* Hall	(c)
5	*Schizodus chemungensis* (Con.) Hall var. *quadrangulus* Hall	(rr)
6	*Lyriopecten tricostatus* (Van.) Hall	(rr)
7	*Bellerophon maera* Hall (?)	(rr)

XXXIV A^4. Some 65 feet higher and about one and one fourth miles northwest of Bainbridge is a ledge on the hillside composed of a rather irregular olive sandstone, with a tendency to concretionary structure. There are some fossils specially in certain layers, the following species having been collected in a few moments:

1	*Spirifer mesastrialis* Hall	(rr)
2	*Productella lachrymosa* (Con.) Hall	(c)
3	*Schizodus chemungensis* (Con.) Hall var. *quadrangulus* Hall	(rr)
4	*Spirifer mucronatus* (Con.) Bill. var. *posterus* H. & C.	(a)

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[a] Proc. Am. ass'n for the adv. science, 1886, 34:226, 231 and section 10 of the chart on the Meridional sections of the upper Devonian deposits of New York, Pennsylvania and Ohio.

At the top of the hill over two miles northwest of Bainbridge and 135 feet above the base of the concretionary sandstone, olive shales outcrop by the side of the highway. On the accompanying section these shales are called A^5. No fossils were discovered though this may be due to the fact that very little time could be spent in searching for them.

LXVIII C^1. Near the southeastern corner of Bainbridge is the small village of Bennettsville just below which on Bennett's creek is a mill. On the north bank of the creek directly above the highway and below the dam are ledges of thin sandstones and bluish, slightly arenaceous shales containing small Lamellibranch shells of which *Leptodesma sociale* Hall, *Orthonota undulata* Con., and *Lunulicardium fragile* Hall are the most common. Fossils are not abundant and though in the upper part of the exposure some calcareous layers, composed largely of crinoid segments, are seen, still none of those strongly calcareous layers containing numerous Brachiopods, that occur rather frequently in the fossiliferous beds of the lower Chemung of this region, were found. The base of the rocks is approximately 65 feet above the level of the Susquehanna river, and in the bank 29 feet are exposed. The following species were collected:

1 *Productella lachrymosa* (Con.) Hall (?) (rr)
Broken specimen very similar to this species.

2 *Orthonota undulata* Con. (c)
3 *Leda diversa* Hall (r)
4 *Modiomorpha quadrula* Hall (r)
5 *Lunulicardium fragile* Hall (c)
6 *Grammysia zonata* Hall (?) (rr)
7 *Leptodesma sociale* Hall (c)
8 *Leptodesma* sp. (rr)
9 *Nucula* sp. (rr)
Very small specimen, unlike any of the figures.

10 (?) *Prothyris* sp. (rr)
11 Crinoid segments (c)

Near the township line one and one quarter miles southeast of Bennettsville loose on the surface and in the stone walls are numerous blocks composed to a large extent of fossils. Specially abundant are *Spirifer mesastrialis* Hall and *S. mucronatus* (Con.) Bill. var. *posterus* H. & C. There are also some specimens of the large Lamellibranchs of the Chemung, as *Lyriopecten tricostatus* (Van.) Hall. A farmer residing in that neighborhood stated that the fossiliferous blocks or the "shell rocks" as he called them were more abundant on the northern than on the southern side of the creek. From loose blocks in this vicinity the following species were collected:

1	*Spirifer mesastrialis* Hall	(a)
2	*S. mucronatus* (Con.) Bill. var. *posterus* H. & C.	(aa)
3	*Liorhynchus globuliformis* (Van.) Hall	(rr)
4	*Schizophoria impressa* (Hall) H. & C.	(rr)
5	*Modiomorpha quadrula* Hall	(c)
6	*Sphenotus* cf. *contractus* Hall	(rr)
7	*S.* cf. *clavulus* Hall Both species imperfectly preserved.	(rr)
8	*Lyriopecten tricostatus* (Van.) Hall	(c)
9	*Cyrtina hamiltonensis* Hall	(rr)
10	*Bellerophon maera* Hall	(c)

Afton

To the south of Bainbridge and Coventry is Afton, the southeastern township of Chenango county, which is bounded on the east by Delaware county and on the south and partly on the west by Broome county. The township is crossed diagonally from the northeast to the southwest by the Susquehanna river, the largest tributaries of which are from the north. Two of these, Bump's creek and Kelsey brook, unite near Afton village; while the third, Wylie brook, crosses the extreme western part of the township.

LXIX A[1]. About one mile above Afton on the south side of the Susquehanna river and from 20 to 25 feet above its level a few

Plate 2

feet of fossiliferous olive shales and thin sandstones are exposed by the side of the highway. Only a brief search was made and the following list might undoubtedly be increased:

1	*Spirifer mucronatus* (Con.) Bill. var. *posterus* H. & C.	(r)
2	*Productella lachrymosa* (Con.) Hall	(c)
3	*Stropheodonta demissa* (Con.) Hall	(rr)
4	*Grammysia undata* Hall (?) Broken specimen.	(rr)
5	*Liorhynchus globuliformis* (Van.) Hall	(rr)
6	Lamellibranch ? Too badly broken to be identified.	(rr)

These rocks are clearly above the Oneonta formation and in the zone which is referred in this report to the lower part of the Chemung. Darton in describing the Oneonta-Chemung boundary from Franklin, Delaware county westward, said: "It extends along the slopes south of Unadilla and Sidney down the Susquehanna to a couple of miles below Afton."[a] On the *Geologic map of New York* the top of the Oneonta formation is represented as extending down the Susquehanna river valley rather more than two miles below Bainbridge to the mouth of Bennett's creek and up this creek to the vicinity of Bennettsville. If this line be correct then the rocks of LXVIII C^1 in the creek below Bennettsville must be quite near the bottom of the Chemung.

LXIX B^2. To the north of the village of Afton is a rocky gorge in Bump's creek, the lower end of which is scarcely one fourth mile from the center of the village. The base of the rocks at the lower end of the gorge is 50 feet above the Susquehanna river, and some 85 feet are shown along the gorge, the upper 10 feet being by the roadside above Pixley's mill. The rocks consist mainly of olive shales alternating with sandstones six inches to one foot in thickness. There are some quite calcareous layers composed largely of shells; one of these occurs in the gorge just below the Pixley mill in which are large numbers of specimens

[a] Am. jour. science, 3d ser., 45:207.

of *Spirifer mucronatus* (Con.) Bill. var. *posterus* Hall & Clarke, and numerous specimens of *Productella lachrymosa* (Con.) Hall. A little above in a thin sandstone are a considerable number of specimens of a large *Schizodus*, referred to *S. chemungensis* (Con.) Hall var. *quadrangularis* Hall. In the bed of the creek is a somewhat concretionary contorted stratum below the calcareous one which is thicker than the majority of such strata in the Hamilton and Chemung series of eastern New York. This is a good locality for collecting in the lower Chemung as the following list will show:

1 *Spirifer mucronatus* (Con.) Bill. (aa)
   var. *posterus* H. & C.

2 *S.* *mesastrilis* Hall (rr)

3 *Productella lachrymosa* (Con.) Hall (a)

4 *Schizophoria impressa* (Hall) H. & C. (rr)

5 *Liorhynchus globuliformis* (Van.) Hall (r)

6 *Camarotoechia contracta* (Hall) H. & C. (aa)

7 *Schizodus chemungensis* (Con.) Hall (c)
   var. *quadrangularis* Hall
   These are rather large specimens 43 mm long and 35 mm high but this is the only species similar in outline.

8 *Palaeoneilo brevis* Hall (a)
   var. *quadrangularis* Hall
   Abundant on one slab.

9 *P.* *filosa* (Con.) Hall var. (rr)
   The concentric striae are fine all over this species until the posterior slope is reached when they suddenly become sharp and angular.

10 *Sphenotus* sp. (r)
   Small and poorly preserved.

11 *Grammysia* cf. *undata* Hall (r)
   Broken specimens.

12 *Ectenodesma birostratum* Hall (rr)

13 *Lyriopecten* cf. *priamus* Hall (r)
   The ribs of the large specimen have finer striae on them and a smaller rib alternating with the larger ones.

14 *Bellerophon maera* Hall (?) (rr)

15 Bryozoan sp. (rr)

16 *Goniophora chemungensis* (Van.) Hall (?) (rr)

Only one specimen and that smaller than the normal forms.

17 *Stropheodonta demissa* (Con.) Hall (?) (rr)

18 *Lyriopecten tricostatus* (Van.) Hall (rr)

19 *Schizodus chemungensis* (Con.) Hall (rr)

20 (?) *Microdon* (*Cypricardella*) sp. (rr)

A large but broken specimen.

LXIX B^4. For some distance up Bump's creek, above the gorge, there are no exposures; but about one and three fifths miles northwest of Afton there is a fair outcrop of sandstones and bluish to olive shales. The base of B^4 is some 95 feet higher than the top of B^2 or 230 feet above the Susquehanna river, and 10 feet of rocks are exposed. The top of the exposure is at the highway bridge on the cross road just below the dam. One irregular, contorted sandstone layer was noticed, as well as a calcareous one composed largely of shells. There is a tendency in the shale to split across the bedding as well as along its plane so that it breaks into thin, narrow strips. Fossils are common specially in the bluish, somewhat arenaceous shales to thin sandstones, *Spirifer mucronatus* (Con.) Bill. var. *posterus* H. & C., *Liorhynchus globuliformis* (Van.) Hall and *Productella lachrymosa* (Con.) Hall being the most abundant. The entire list follows:

1 *Liorhynchus globuliformis* (Van.) Hall (c)

2 *Productella lachrymosa* (Con.) Hall (c)

3 *Spirifer mucronatus* (Con.) Bill.
var. *posterus* H. & C. (a)

4 *Camarotoechia congregata* (Con.) H. & C. (?) (a)

These specimens are rather intermediate between the above species and *C. contracta* Hall.

5 *Stropheodonta demissa* (Con.) Hall (rr)

6 *Microdon* (*Cypricardella*) cf. *bellistriatus* (Con.) (rr)

In form and size like the above but the striae are like those of *M. tenuistriatus* Hall.

7 *Palaeoneilo brevis* Hall (rr)

8 *Palaeoneilo* sp. (rr)

9 *Leptodesma sociale* Hall (rr)
10 *Lyriopecten tricostatus* (Van.) Hall (rr)
11 *Bellerophon maera* Hall (rr)
12 *Pleurotomaria* sp. (rr)
Very imperfectly preserved.
13 *Orthoceras leander* Hall (?) (rr)
14 *Modiomorpha quadrula* Hall (rr)

The rocks described above, from along Bump's creek, are in the lower part of the Chemung as it has been defined in this report and this creek together with the one at Bainbridge affords a fair opportunity for the examination of this part of that formation. The creek valley was followed from above B^4 at the saw mill to a point near the township line between Afton and Coventry; but it is fairly broad and somewhat marshy and the rocks are covered with drift so that no further exposures of any importance were seen.

LXX A^1. To the north of Harpersville is a brook whose southerly course is near the township line between Afton and Colesville. On the bank, a short distance above the iron railroad bridge on the Binghamton division of the Delaware and Hudson railroad, are olive shales, most of which are somewhat arenaceous, and sandstones which are mainly in a contorted layer.

The base of the exposure is about 70 feet below the Harpersville station and only a few feet lower than that at Afton. *Spirifer mucronatus* (Con.) Bill. var. *posterus* H. & C. is common in these shales while in loose blocks along the creek are numerous specimens of *Spirifer mesastrialis* Hall. The following additional species were found in the loose pieces:

1 *Spirifer mucronatus* (Con.) Bill. var. *posterus* H. & C. (a)
2 *Productella lachrymosa* (Con.) Hall (r)
3 *Camarotoechia* cf. *congregata* (Con.) H. & C. (c)
4 *Grammysia communis* Hall (rr)

LXX A^3. Farther up the stream and 40 feet above the base of A^1 is an exposure of greenish to olive sandstone on the bank of

the brook with some bluish arenaceous shales at the base. In the sandstone is an irregular concretionary layer and the thickness of the rocks exposed at this locality is 10 feet. No fossils were found.

LXX A^5. Along the main brook no further outcrops were found above A^3 for the valley seems to be quite deeply covered with drift; but in a small run from the west and nearly west of a red schoolhouse are outcrops of shales and sandstones. The base of this zone is 115 feet above the top of A^3 and for 95 feet there is a nearly continuous rock section consisting mainly of thin bedded sandstones in layers six inches or more in thickness with some layers of irregular structure and arenaceous shales. In the upper part are greenish to bluish shales that are more argillaceous in character and there are occasionally thin, rather strongly calcareous, abundantly fossiliferous layers in one of which *Bellerophon maera* Hall is common. The following species were obtained at this locality:

1	*Liorhynchus globuliformis* (Van.) Hall	(r)
2	*Bellerophon maera* Hall Common in some very calcareous layers.	(c)
3	*Grammysia* sp.	(r)
4	*Palaeoneilo brevis* Hall	(r)
5	*P.* *plana* Hall	(rr)
6	*Modiomorpha quadrula* Hall	(rr)
7	*Leda brevirostris* Hall	(rr)
8	*Leptodesma sociale* Hall	(r)

For 110 feet from the top of A^5 nearly to the top of the hill the rocks are covered by drift and soil and no higher outcrops were found at this locality. The section may be represented diagrammatically as follows:

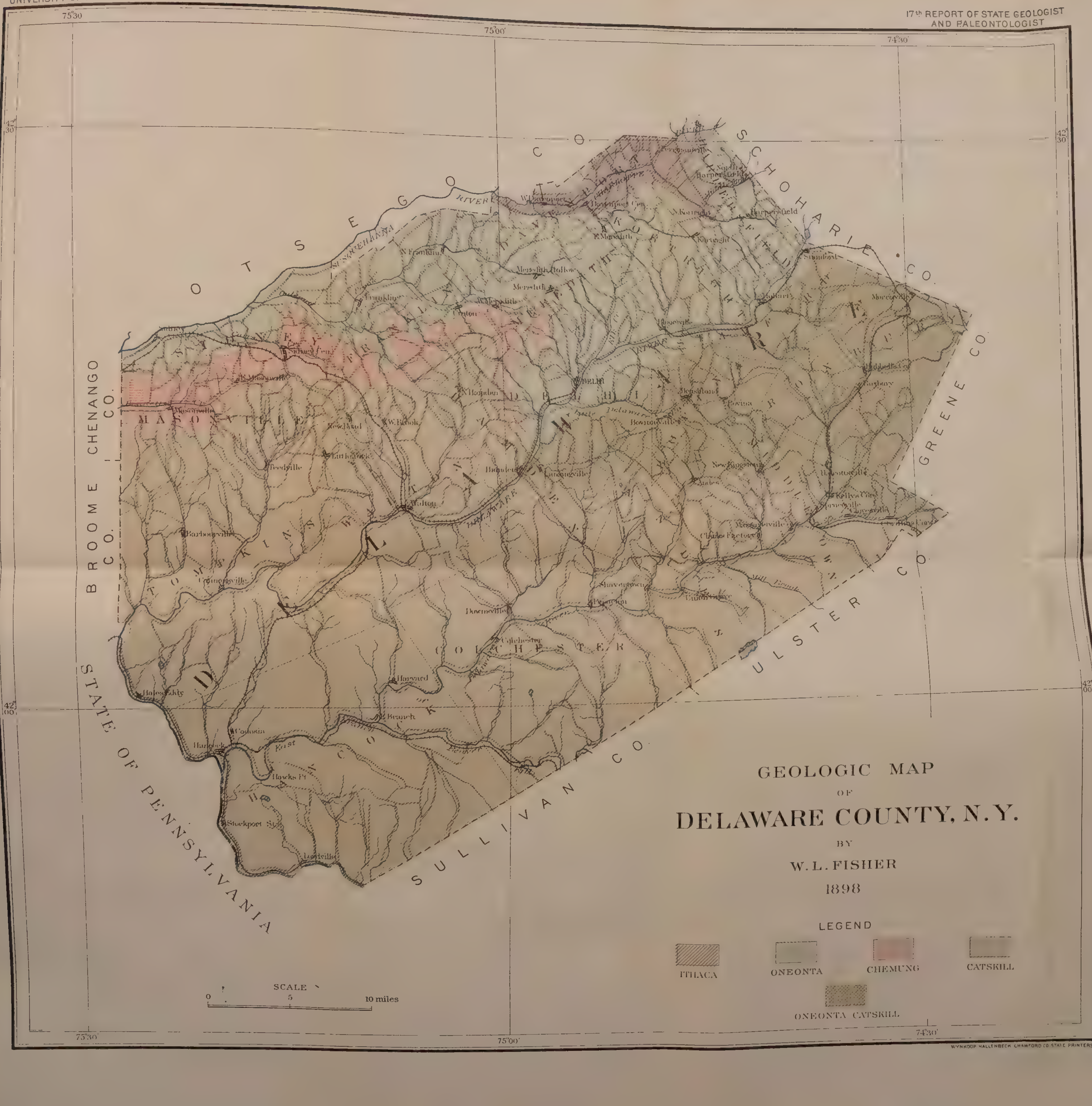
SECTION NORTH OF HARPERSVILLE

LXX A

370′		
	110′	A[6] Covered nearly to the top of the hill
260′		
	95′	A[5] Sandstones and shales for most of the distance along the run
165′		
	115′	A[4] Covered
50′		
	10′	A[3] Sandstone with shale at base
40′		
	40′	A[2] Covered
		A[1] Olive shales
0′		Creek level above railroad bridge

The divide between the Susquehanna and Chenango rivers which crosses the western central part of Colesville township from north to south is quite heavily covered by drift so that outcrops of rocks are rather infrequent; but along the streams on the western side are occasional exposures; those in the vicinity of Osborne Hollow, near the western line of Colesville township, were described in part 1 of this report[a], and to the west near the top of the high hill south of the Chenango river below Port Crane

[a] 15th an. rep't N. Y. state geologist, p. 160-62.



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the characteristic Chemung species *Spirifer disjunctus* Sowb. was found[a], showing conclusively that these higher rocks are of Chemung age.

DELAWARE COUNTY

To the east of Broome and Chenango counties and south of the Susquehanna valley and Otsego county is Delaware county which is crossed by the Delaware river from the northeast to the southwest. The geology of this county is interesting from the fact that as the Chemung formation is followed from the Susquehanna valley eastward into Delaware county it thins rapidly from the upper part downwards, being replaced by rocks consisting of coarse grained gray sandstones, alternating with red sandstones and red and greenish argillaceous shales similar to those found in the Catskill formation in the Catskill mountains. This change in lithologic characters is found to have occurred quite rapidly, for on passing to the east of the Delaware river in the vicinity of Delhi we see that the characters of the Catskill rocks have nearly replaced those of the Chemung; the replacement being from the top and the lower part of the Chemung extending farthest to the east. However, after crossing the Delaware river it is difficult to recognize the Chemung formation and in the eastern part of the county there is a section of red and gray sandstones alternating with red and greenish shales from the base of the Oneonta sandstone to the tops of the highest hills which are clearly in the typical Catskill formation.

Masonville

To the east of Afton and Bainbridge is Masonville which is one of the western tier of townships in Delaware county. The northern central part of the township is crossed from the east to the west by Bennett's creek which heads partly in the small glacial lake east of East Masonville near the township line between Masonville and Sidney. Exposures on the banks of this creek below Bennettsville, in the southeastern part of Bainbridge

[a] 15th an. rep't N. Y. state geologist, p. 160.

which are near the base of the Chemung formation, have already been described.

LXVIII B[1]. By the side of the highway on the southern side of Bennett's creek, one mile west of Masonville is a small outcrop of grayish thin bedded sandstone. On splitting, the surface of the layers is somewhat rough. Fossils are not uncommon in this sandstone and the species listed below were collected:

1 *Camarotoechia eximia* (Hall) H. & C. (c)

2 *Goniophora* cf. *trigona* Hall (rr)

Imperfectly preserved.

3 *Edmondia* cf. *subovata* Hall (r)

4 *Actinopteria* sp. (r)

Quite imperfect.

LXVIII A[1]. On the south side of the road to the east of Masonville is a small quarry. The rock consists of olive to greenish argillaceous shales and flaggy sandstones varying from light gray to greenish which are quarried to some extent for local use. It is not, however, a quarry of any special importance. Fossils are rare and some little search yielded but one species—*Orbiculoidea* cf. *neglecta* (Hall) Schuchert. The rocks along Bennett's creek across Masonville township are in the Chemung formation.

Sidney

Sidney is the northwestern township of Delaware county, being situated north of Masonville and south of the Susquehanna river. It is bounded on the north by Unadilla and Otego townships, Otsego county, and on the east by Franklin township, Delaware county. The central part of the township is crossed by Carrs creek, which flows from the southeast toward the northwest and enters the Susquehanna river opposite the village of Unadilla. On the southern side of the creek are quite steep hills forming the divide between it and Bennett's creek. The creek valley and this range of hills afford occasional sections, though the rocks are largely covered by soil and drift.

LXVII B^2. At the three corners on the northern side of Carrs creek nearly two miles northwest of Maywood (formerly Sidney Center) is an exposure of thin bedded red sandstone. One foot or more of the stratum is shown in a small brook just north of the highway; the top of which is about 33 feet above the level of Carrs creek. This outcrop is in the Oneonta formation and near its top as is shown by the exposures in the railroad cut on the southern side of the creek.

LXVII B^4. On the southern side of Carrs creek, two miles northwest of Maywood, is quite an extensive railroad cut the base of which is 95 feet above the creek level. The rocks shown in the cut are mostly olive shales and sandstones with some blue shale. At one place is a spot of shale which is somewhat reddish, perhaps from weathering, but olive at each end. A contorted layer of sandstone occurs, and the cut shows a section 33 feet in thickness. Fossils are not common, with the exception of Crinoid segments, but the following species were found by Mr William L. Fisher:

1 *Spirifer mucronatus* (Con.) Bill. (c)
var. *posterus* H. & C.
Poorly preserved.

2 *Orthonota* (?) *parvula* Hall (rr)
3 *Sphenotus* cf. *contractus* Hall (rr)
4 *Goniophora* cf. *Hamiltonensis* Hall (rr)
5 *Tentaculites* cf. *spiculus* Hall (a)
Abundant on some layers.

6 Large Lamellibranch very poorly preserved (rr)
7 Crinoid segments (a)
Small segments abundant on some layers.

The rocks exposed in this cut are near the base of the first fossiliferous zone above the Oneonta sandstone which, as already stated, is referred to the base of the Chemung formation in this report. At the maximum the base of the cut can hardly be more

than 60 or 65 feet above the top of the Oneonta sandstone. The above section may be tabulated as follows:

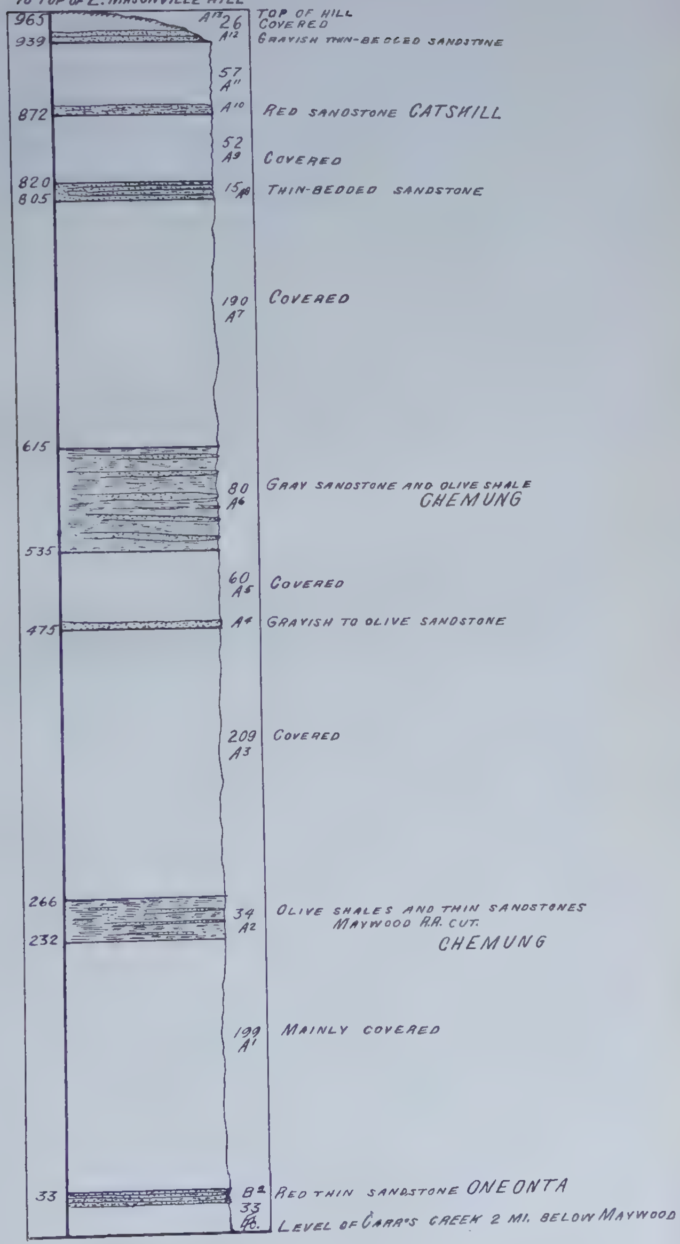
128′		
	33′	B^4 Olive shales and sandstones. *Chemung*
95′		
	62′	B^3 Covered
33′		
	1′	B^2 Red sandstone. *Oneonta*
	32′	B^1 Covered
0′		Level of Carrs creek

The above section agrees fairly well with exposures near Youngs, one mile farther northwest, where in the railroad cut directly north of the station there are olive and bluish fissile shales alternating with thin, irregular sandstones. There are also irregular, concretionary sandstones. Fossils are rare, but a few specimens of *Atrypa reticularis* (Lin.) Dal. were found.

In a quarry about 60 feet below the railroad track on both sides of Ford creek are unfossiliferous coarse gray sandstones which split quite regularly making small flags, and an occasional layer of clay pebble conglomerate. In the creek just below the quarry are large slabs of red sandstone which are probably about in place. The rocks of this quarry belong, apparently in the Oneonta formation.

About 75 feet lower on the western side of Carrs creek there is a steep bluff in which large masses of angular red sandstones

No. 67, A & B. SECTION
THROUGH
MAYWOOD
TO TOP OF E. MASONVILLE HILL



occur. They are hardly in place, still from their very angular shape and the large number of them they must form a ledge in that immediate vicinity.

LXVII A². In the cut immediately west of Maywood station (formerly Sidney Center) on the New York, Ontario and Western railroad there is an exposure of 34 feet of thin sandstones alternating with shales. Some of the thin layers contain large numbers of Crinoid segments, and the rock being quite calcareous becomes rotten on weathering and turns from a greenish to a brownish color. Some of the shales when weathered are olive but on a fresh surface are mostly bluish. The bottom of the railroad cut is at about the same level as the Maywood station which is 1388 feet A. T. The dip varies for the different strata exposed in this cut; for one stratum dips about 1° nearly s. e., while that of a lower thin sandstone stratum varies from $1\frac{1}{2}°$ to $2\frac{1}{2}°$ S. 10° E. In number of species and specimens Lamellibranchs are most abundant though other fossils are common. The list is as follows:

1	*Liorhynchus mesacostalis* Hall	(rr)
2	*Camarotoechia* cf. *stevensi* (Hall) H. & C. Broken and imperfectly preserved.	(rr)
3	*Spirifer mesastrialis* Hall	(r)
4	*Palaeoneilo constricta* (Con.) Hall	(rr)
5	*P.* sp.	(c)
6	*P. plana* Hall (?)	(rr)
7	*Nuculites oblongatus* Con.	(rr)
8	*Orthonota* (?) *parvula* Hall.	(r)
9	*Leda diversa* Hall	(c)
10	*Sphenotus* cf. *contractus* Hall	(a)
11	*Grammysia* cf. *communis* Hall	(rr)
12	*G. elliptica* Hall	(rr)
13	*Leptodesma* cf. *sociale* Hall	(c)
14	*Ptychopteria* sp.	(rr)
15	*Lunulicardium fragile* Hall	(rr)

16 *Orbiculoidea* sp. (rr)

Imperfectly preserved.

17 *Orthoceras* sp. (rr)

18 Crinoid segments

On some layers immense numbers of small segments.

The base of this cut is approximately 199 feet above the red sandstone of $67B^2$, or 137 feet higher than the bottom of the railroad cut at $67B^4$, two miles farther northwest, and is, consequently, at least that much higher stratigraphically in the Chemung formation.

The high hill to the west of Carrs creek, south of Maywood, affords an opportunity to measure the thickness of the Chemung formation. A section has been constructed showing the rocks from the level of Carrs creek at $67B^1$ to the top of the high hill near the Sidney-Masonville township line south of Maywood. The course of this section from Maywood south is up the valley of Carrs creek to the first road turning west and then over the hill to East Masonville. Unfortunately in measuring the section that route was not followed so that the covered zone called A^3 and estimated as 209 feet in thickness may vary to quite an extent from that approximation. On this hill the grayish to olive sandstones were noted at the horizon A^4 which is estimated as 475 feet above the level of Carrs creek at B^1, and they continue to at least an altitude of 615 feet the last 80 feet of which are composed largely of rather coarse grained grayish sandstone and some olive shale. This zone is apparently in the Chemung although a hasty search was not rewarded with fossils. Supposing B^2 to be the top of the Oneonta sandstone and the zone just described the top of the Chemung formation, the thickness of the Chemung in this section would then be approximately 580 feet. From the bottom of the railroad cut at B^4, which is unquestionably in the Chemung, to the top of A^6 is, approximately, 510 feet. Above A^6 for 190 feet the rocks are covered when 15 feet of thin, irregularly bedded, rather fine grained grayish to greenish sandstone occur in zone A^8. The first ledge of red sandstone and shale seen on this hill which is clearly in the

Catskill formation is found 52 feet higher. A piece of loose sandstone containing a specimen of *Spirifer mesastrialis* Hall was found below the ledge of red sandstone but I am hardly inclined to think that it came from the upper part of this hill. 57 feet above the red sandstones and shales occurs another ledge—A^{12}—of grayish thin bedded sandstones which are 939 feet above the base of the section. The rocks are then covered for 26 feet, nearly to the summit of the hill, making a section of approximately 965 feet which extends from the upper part of the Oneonta sandstone into the lower part of the Catskill formation.

LXVII C^1. The section C is in the vicinity of Franklin Station on the New York, Ontario and Western railroad, three and one half miles southeast of Maywood and near the line between Sidney and Franklin townships. On the bank of the small brook below Franklin Station and east of the railroad cut is a 10 foot exposure of olive to gray colored sandstones and shales containing plenty of Crinoid segments with a few other fossils. The rocks are in the Chemung formation.

LXVII C^3. In the railroad cut about one quarter mile northwest of Franklin Station is an exposure of 28 feet of rocks the base of which is 66 feet above C^1. The rocks consist of rather thin layers of sandstone alternating with olive and blue argillaceous shales. In the lower part of the cut is a stratum composed partly of shale and partly of sandstone which has very irregular structure and is probably somewhat concretionary in form. The dip varies from $2\frac{1}{2}°$ to $3\frac{1}{2}°$ S., 20° E. In some of the layers fossils are common and in the rather thin layers of sandstone quite a number of specimens of *Spirifer mesastrialis* Hall were found. The thin olive shales and sandstones quite closely resemble, lithologically, the typical Chemung rocks of southern New York. The fauna of this zone is as follows:

1	*Spirifer mesastrialis* Hall	(c)
2	*Atrypa reticularis* (Lin.) Dal.	(rr)
3	*Goniophora subrecta* Hall	(c)

4 *Palaeoneilo brevis* Hall (c)
5 *Leda* cf. *diversa* Hall (r)
6 (?) *Grammysia zonata* Hall (c)
7 *Lyriopecten priamus* Hall (rr)
8 *Onychodus hopkinsi* Newb. (r)
9 *Dinichthys tuberculatus* (?) Newb. (rr)

The last two specimens were identified by Dr Eastman.

LXVII C^5. There are but few outcrops on the hill to the south of Franklin Station, its slope being well mantled by the drift. However on the summit of the hill one mile south of the station is a ledge of thin bedded olive to light gray sandstone which splits into quite thin layers at the surface but thickens as the unweathered part is reached. A small excavation has been made exposing four and a half feet of the ledge. There is an occasional fossil, fragments of Brachiopods and ? *Cladochonus* sp., which indicates that the top of this hill is in the Chemung formation.

A section based upon barometric readings has been constructed from the level of Carrs creek at B^1 along the creek valley to C^1 near Franklin Station and then to the top of the hill south of the station. Without making any allowance for the dip which would increase rather than diminish the thickness of the rocks, it will be seen that from the top of the Oneonta red sandstone B^2 to the top of the hill C^5 south of Franklin Station there is a thickness of 547 feet. Or from the base of the railroad cut B^4, two miles northwest of Maywood, which is in the Chemung, to the top of C^5 south of Franklin Station there is a thickness of 485 feet. The top of the hill C^5 south of Franklin Station is near the same elevation as the top of zone A^6 on the hill south of Maywood which was also referred to the Chemung, and it seems hardly probable that C^5 extends to the top of the Chemung. This section along the N. Y. O. & W. railroad indicates that for Sidney township the Chemung formation has a thickness of more than 500 feet.

Franklin

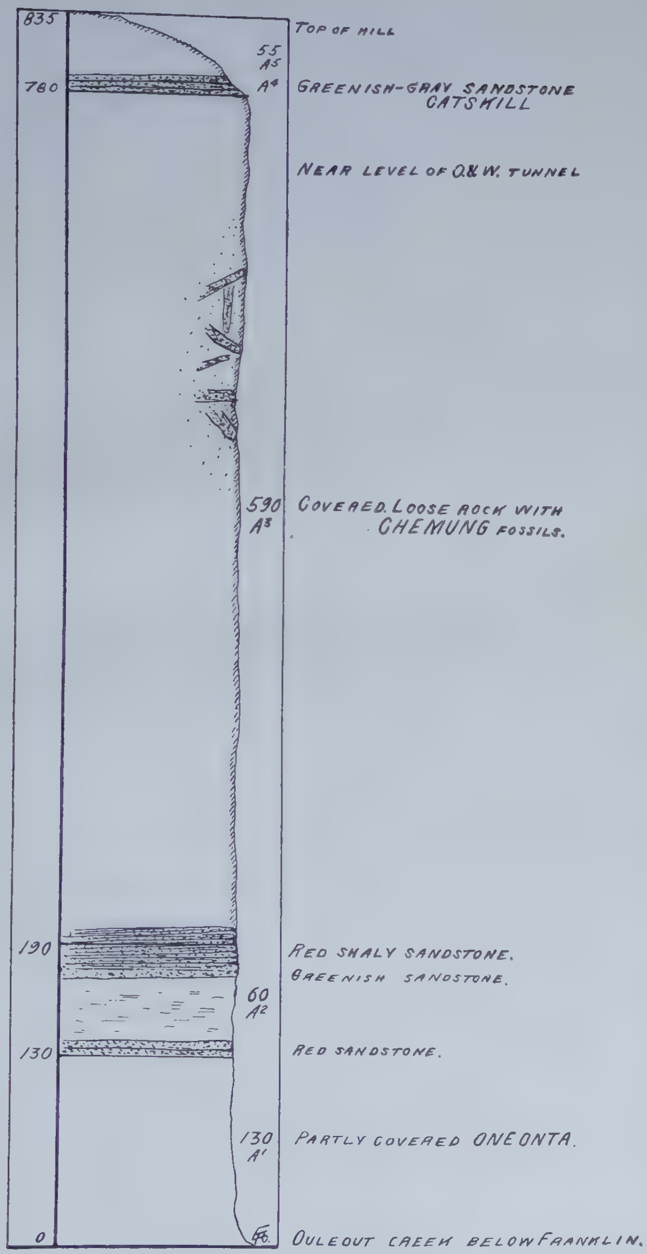
To the east of Sidney is Franklin township, which is bounded on the north by the townships of Otego and Oneonta, Otsego county. The principal stream is Ouleout brook which crosses the township in a general direction from the east to the west and flowing across the northern part of Sidney township enters the Susquehanna river between Unadilla and East Unadilla.

XXXIII B[1]. In the southwestern corner of the township is the tunnel on the New York, Ontario and Western railroad about half way between the Merrickville and North Walton stations and two and one half miles southeast of Franklin Station. Before the excavation of the tunnel the railroad crossed the ridge by means of a "zig zag" which served as the name of the locality. This ridge forms the divide between the head waters of the streams entering the Susquehanna river on the north, and those flowing into the Delaware river on the south. The floor of the tunnel is 1764 feet A. T. at the southern end and it is 1636 feet in length. The approach to the southern end shows about 40 feet of solid rock consisting of fairly massive and shaly sandstones alternating with arenaceous and argillaceous shales. The lower rocks are mainly of bluish gray sandstone, then at the middle of the cut are red shales and sandstones from 10 to 15 feet in thickness and on top of these grayish to greenish and bluish sandstones and shales. To the south of the southern end of the tunnel and only a short distance north of the North Walton station large quantities of rock taken from it were dumped. Red shale apparently predominates, though there is a large amount of greenish to bluish shale in which are numerous specimens of Lamellibranch shells. In a rock slightly more irregular in texture plenty of fish scales and bones were found with which were associated *Lingula* and a few other shells. *Archaeopteris* and fragments of other plants were found in argillaceous shales on the dump and in the approach to the tunnel. The northern end of the tunnel is lower than the southern and in the approach it is all massive greenish gray sandstone of somewhat irregular bedding

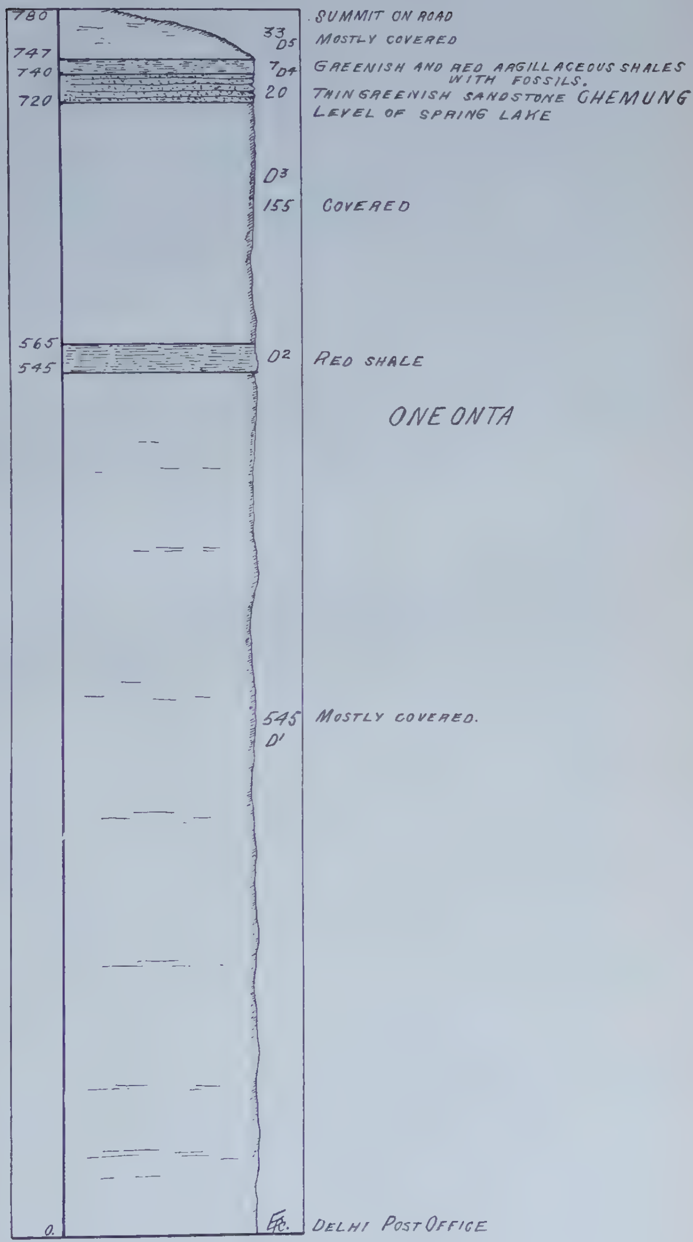
with shale partings. Only a few rods north of the entrance to the tunnel on the east side, *Lingula* associated with plant stems was found in place, while in some of the greenish shales specimens of *Liorhynchus* occur. A little west of the highway and railroad is a quarry of coarse greenish gray flagstone in which some of the layers have a slightly pinkish tint. To the north of the tunnel is quite an extensive fill, the material for which came from it, and when first visited about two months after the opening of the tunnel in 1891, there were plenty of large blocks of red shale to be seen which contained numerous specimens of *Lingula* and other shells associated with the bones and scales of fish. When visited in 1895, however, the fossiliferous shales taken from the tunnel and dumped at both the northern and southern ends were so badly slacked by weathering that collecting was very unsatisfactory. It is possible that deeper blocks may yet remain unweathered from which fair specimens might be obtained. The rocks from this tunnel are probably in the lower part of the Catskill formation and affording quite an extensive fauna they become important from a paleontological standpoint. In fact quite a good many of the specimens came from red, argillaceous shales while the massive greenish gray sandstone below the red at the northern end of the tunnel resembles the coarse sandstones of the Catskill. The ichthyic remains were studied by Dr C. R. Eastman of Harvard university, the well known authority in ichthyic paleontology who kindly prepared the interesting account of these fossils given at the close of this report. He identified *Bothriolepis minor* Newb. and *Onchus* sp. Eastman.

XXXIII A^2. The village of Franklin is located in the valley of Ouleout brook from 400 to 500 feet lower than the New York, Ontario and Western railroad tunnel between Merrickville and North Walton. A mile and a half below Franklin a brook enters the Ouleout from the south and a section was constructed from the Ouleout level to the top of the hill on the south between the Franklin Station and Merrickville highway. The rocks along the valley of Ouleout brook are very largely red

No. 33. A. SECTION
SOUTH OF
FRANKLIN



No. 65, D. SECTION
NORTHWEST OF
DELHI TO SPRING LAKE



argillaceous shales with some sandstones belonging in the Oneonta formation. Along the brook and highway from the Ouleout valley toward Franklin Station the rocks are partly covered for 130 feet, reds showing now and then, when a conspicuous red sandstone crosses the brook. 60 feet higher and just below the forks in the road is an outcrop of red, shaly sandstone alternating below with greenish layers of sandstone. This locality is about two miles from the tunnel and is, apparently, at about the top of the Oneonta formation. Loose along the brook and in the fields are numerous blocks of sandstone containing large numbers of Crinoid segments. Unfortunately the northern slope of the hill is generally deeply covered with drift and no exposures of these fossiliferous rocks were found. From loose blocks in the side of the hill the following species were collected:

1	*Goniophora chemungensis* (Van.) Hall	(rr)
2	*Palaeoneilo constricta* (Con.) Hall	(r)
3	*Nuculites cuneiformis* Con.	(rr)
4	*Leptodesma sociale* Hall	(rr)
5	*L.* sp.	(rr)
6	*Camarotoechia* sp.	(rr)
7	*Pleurotomaria* sp.	(rr)
8	*Tentaculites* sp.	(rr)
9	Crinoid segments	(aa)

Very abundant in some of the pieces.

They belong, however, in the Chemung formation which was estimated by Darton to "have a thickness of about 300 feet"[a] to the south of Franklin. At 590 feet above the top of the Oneonta red sandstone noted in the brook is a ledge of greenish gray sandstone somewhat unevenly bedded (A^4) near the top of the hill which is some 55 feet higher, and on its surface are numerous blocks of red sandstone. No red rock was found in place, but as this hill barometrically is some 190 feet above the Merrickville station it seems probable that its upper part, including the

a Am. jour. science, 45: 207.

coarse, greenish gray sandstone of A^4, is in the Catskill formation. However, farther to the east and on the other side of the small valley are thin bedded, grayish sandstones near the summit of the hill, which contain occasional small Crinoid segments. To the east of the road north of Merrickville at the above locality there is a ledge of this sandstone eight feet in thickness, and about 25 feet higher on the highest point of the hill are ledges of coarser grained grayish sandstone. On the western side of the road at the head of the small brook and narrow valley and 80 feet lower is a ledge of finer gray sandstone some 15 feet in thickness.

XXX D^2. One fourth mile south of Franklin village is a steep and rather high hill between the Ouleout and Handsome brook valleys known as Round Top. The lower part of the hill being somewhat covered only occasional outcrops of red and gray sandstones and shales occur and at an altitude of 234 feet above the level of Ouleout brook is a stratum of breccia, eight inches or so in thickness, above which is red sandstone. The red rocks continue to 332 feet where the last ledge of thin, red sandstone was seen. 10 feet higher is the bottom of D^3, a zone composed of slightly greenish to grayish thin bedded and shaly sandstones which continues for about 45 feet to the top of the hill. Some of the layers contain fossils the most abundant being crinoid segments but *Atrypa reticularis* (Lin.) Dal., several species of Lamellibranchs, and fragments of fish were also found. The top of this hill is clearly in the zone which is referred to the lower part of the Chemung in this report. The following species were found in the shaly sandstones of D^3:

1	*Atrypa reticularis* (Lin.) Dal.	(r)
2	*Sphenotus contractus* Hall (?)	(rr)
3	*Grammysia elliptica* Hall	(rr)
4	*Edmondia* cf. *philipi* Hall	(c)
5	*E.* cf. *subovata* Hall	(rr)
6	*Goniophora subrecta* Hall	(rr)
7	*Prothyris* cf. *lanceolata* Hall	(rr)

8 *Lyriopecten* sp. (rr)

Poorly preserved specimen.

9 *Orthoceras* sp. (rr)

10 Crinoid segments (c)

11 Fish scale (rr)

SECTION OF ROUND TOP HILL

XXX D

387′		Top of Round Top
	45′	D^3 Greenish to grayish sandstones. *Chemung*
		First fossils
332′		Last red sandstone
	98′	D^2 Red and gray sandstone
234′		Breccia layer *Oneonta*
	234′	D^1 Partly covered Red and gray sandstones and red shales
0′		Level of Ouleout creek

Franklin township has occupied a rather conspicuous position in the geological literature of Delaware county since the announcement of the discovery of fossils, by Mr J. M. Way, in rocks which up to that time had been considered to belong in the Catskill formation or old red sandstone as it was frequently termed. This discovery was published in the latter part of 1862 by both Prof. Hall and Col. Jewett. In the autumn of that year Prof. Hall examined the rocks of this region in company with Prof. Edward Orton and Mr Way and published an article on its geology[a] which contained "a section from the north side of

a Canadian naturalist and geologist, Oct. 1862, 7:377.

the Susquehanna river to the high hills in the south part of Franklin." In this section Prof. Hall reported "greenish and gray shales and shaly sandstone" as succeeding the Hamilton, then from 400 to 500 feet of "red shale and shaly sandstone with numerous fucoidal remains" which is now known as the Oneonta formation; while succeeding the red shales are about 100 feet of "non-fossiliferous shale and shaly sandstone." The greenish, red, and non-fossiliferous shales and sandstones or numbers 9, 8, and 7 of the section were said to "represent the Portage group." The succeeding 250 to 300 feet of greenish to gray sandstones and shales are stated to contain fossiliferous bands in which are the bones and teeth of fishes associated with Brachiopod and Lamellibranch shells. Among the shells *Spirifer mesastrialis* Hall and *Cypricardites chemungensis* Vanuxem [*Goniophora chemungensis* (Van.) Hall] were mentioned. Capping the hills are from 100 to 150 feet of "greenish gray sandstones and shaly sandstones" in which fossils were not distinctly mentioned. In correlating these upper members of the section Prof. Hall said they "are always marked by characteristic fossils of the Chemung group" and that "having . . . personally examined the region in question, I do not hesitate to say that we have in the fossil remains taken together the most unequivocal evidence of the occurrence of the Chemung group in these localities." Col. Jewett reported that at Franklin he "found Mr J. M. Way, a gentleman who for years has been examining the rock and collecting the fossils; and . . . he has succeeded in investigating the whole strata of the neighborhood and collecting many fossils. With his assistance I was able to make a section from the Ouleout creek to the top of a hill about three miles southwest of the village of Franklin, more than 800 feet in thickness,"[a] Jewett reported about 400 feet of red shale with some red sandstone at the base of this section above which was greenish shales and gray sandstones extending to the top of the hill, the upper 350 feet of which he reported as containing fossils of the Chemung formation to which he referred these rocks stating that he believed "that there is no old red sandstone (Catskill formation) in this state."

a 15th an. rep't regents on state cabinet of natural history, p. 198.

In Prof. Hall's address before the National academy of science in 1880 he again referred to the correlation of the rocks in Franklin,[a] and apparently referred the highest rocks of that township to the Catskill formation. Prof. Hall said "crossing from Oneonta and approaching Franklin over red and mottled shales and sandstones with an apparently southwest dip, these were succeeded by gray and greenish shales and sandstones carrying Chemung fossils; and again on the road to Delhi these latter were succeeded by red rocks . . . The fossiliferous beds of the Chemung are found lying upon that formation [the Oneonta] between Norwich and Oneonta, and to the east of Sidney Plains [Sidney], and at or near Franklin, where they apparently pass beneath the great red sandstone formation of the Catskills, which is characterized by the presence of bones and scales of *Holoptychius*."

Darton, in considering the "stratigraphic relations of the Oneonta and Chemung formations in eastern central New York," reported that "The fossiliferous Chemung shales overlying the Oneonta formation south of Franklin have a thickness of about 300 feet and present the usual Chemung character. They grade upward through a series of flags, into hard, coarse, crossbedded gray sandstones with intercalated red shale layers."[b]

While in Franklin the writer called upon the widow of Mr Way who was killed in the civil war, and she informed him that Round Top hill was one of his best localities for collecting specimens. Another place described to me by Mr E. P. Howe of Franklin, who was well acquainted with Mr Way, is on the western side of Ouleout brook opposite the Franklin mills between 80 and 90 feet above the level of the creek. At this locality there is a ledge of reddish sandstone over thin, gray sandstone and Mr Howe thinks the fossils came from the red rock. There is no question but that this zone is in the upper part of the Oneonta formation. Mr Howe found in grayish sandstone, probably near the base of the Oneonta formation, a fine specimen of *Archeopteris jacksoni* Dn, near the foot of the northern slope of the

a Science, old series, Dec. 11, 1880, 1:290.

b Am. jour. science, 3d ser., 1893, 45:207.

hill between Franklin and Otego in Otego township. The specimen now belongs to the museum of the State university of Ohio and has been kindly loaned by Prof. Edward Orton for the figure which appears in this report.

LXVI A. In the eastern part of Franklin on the southern fork of Ouleout brook is the small village of Treadwell (formerly Croton). To the south of the village is the valley of Roaring brook and a section of 350 feet was studied leading up this valley and toward the summit of the hill on the western side. Directly south of Treadwell on the western side of Roaring brook is an exposure of some 10 feet of red sandstone (A^2) perhaps about 25 feet above the center of the village. This outcrop is in the upper part of the Oneonta sandstone as is shown on the *Geologic map of New York.* For 130 feet on the side of the hill the rocks are covered, then a ledge of thin bedded gray sandstone two feet thick (A^4) occurs. The rocks are then mostly covered for 88 feet when the base of the Prime quarry is reached. However, about 15 feet below its base but farther to the east is a ledge of slightly reddish sandstone. Perhaps the reddish color is due to weathering and it may be considerably above the top of the Oneonta. The rocks are so well covered that on the lower slope of this hill the line of division between the Oneonta and Chemung was not determined. The Prime quarry (A^6) is on the hill about three quarters of a mile south of Treadwell and some 255 feet higher. In the wall of the quarry 13 feet of rocks are shown, the lower eight feet being fairly fine grained, greenish gray flagging stone which splits into flags from two to three inches in thickness. In the debris of the quarry and loose on the hillside are numerous blocks of stone containing large numbers of Crinoid segments. Such a layer filled with these segments occurs near the top of the sandstone. The upper five feet of the quarry is composed mainly of greenish argillaceous shales in which are a few coarser layers containing numerous Crinoid segments. In addition to these a specimen of *Tentaculites spiculus* Hall (?) and another of *Orthonota* (?) *parvula* Hall were found. The rocks forming this quarry are considered to belong in the lower part of the Chemung. 42 feet above the top of the quarry is a five-foot ledge

(A^8) of similar greenish sandstone which thickens toward the top, while 30 feet higher is a four-foot ledge (A^{10}) of thin bedded, grayish sandstone which is the highest outcrop examined on the hill.

TREADWELL SECTION

LXVI A

349′		
	4′	A^{10} Thin bedded grayish sandstone
345′		
	30′	A^9 Covered
315′		
	5′	A^8 Greenish sandstone
310′		
	42′	A^7 Covered
268′		
	13′	A^6 Prime quarry. Sandstone and shale
255′		
		250 (?) slightly reddish sandstone
	88′	A^5 Mostly covered
	2′	A^4 Thin bedded gray sandstone
165′		
	130′	A^3 Covered
35′		
	10′	A^2 Red sandstone
25′		
	25′	A^1 Covered
0′		Center of Treadwell

Darton compared the Chemung section south of Franklin with that at Treadwell (Croton) stating that in tracing the fossiliferous shales of the Chemung eastward from Franklin "they were found to gradually merge into flags and then into harder, coarse sandstones till at Croton, 10 miles east, their horizon is represented by a heavy mass of coarse, gray, crossbedded sandstones with flaggy layers."[a]

Near the township line between Franklin and Meredith and just below West Meredith are ledges of red shale and sandstone on the hillside a little south of the road. This outcrop is about 55 feet above the corners at West Meredith. Another ledge of thin bedded, red sandstone 30 feet in thickness occurs 55 feet higher and this is capped by similar thin bedded gray sandstone. These rocks apparently belong in the Oneonta sandstone and are near the line of division between it and the Chemung as mapped on the *Geologic map of New York*. On a loose block of greenish Chemung sandstone a good specimen of *Schizodus chemungensis* (Con.) Hall was found and in the red sandstone a good specimen of a branching algoid plant. Toward the divide southeast of West Meredith and 215 feet higher is a coarse, massive greenish sandstone which as represented on the *Geologic map of New York* is probably in the Chemung.

When the sections of the rocks overlying the Oneonta sandstone at West Meredith, Treadwell and Franklin are compared with the synchronous deposits on the Susquehanna river at Bainbridge and Afton, the far greater amount of coarse grained sandstone is at once noticed. The shales and somewhat calcareous, fossiliferous layers of the Susquehanna valley Chemung seem to have largely disappeared and to have been replaced by these coarse sandstones. This change is still more marked to the eastward in the drainage area of the Delaware river as will be seen in the description of that region.

Delaware valley

To the south of Franklin and the western part of Meredith township the drainage is southerly into the Delaware river. On

[a] Am. jour. science, 3d ser., 45:207.

account of the comparatively small number of sections of sufficient importance to merit a description, as well as the monotonous repetition of red sandstones and shales alternating with coarse, greenish gray sandstones, it is considered best to describe this region under the general heading of the Delaware valley.

LXV D[4]. In the southwestern part of Meredith township about five miles northwest of Delhi and barometrically 720 feet above the level of the Delhi postoffice is a small, glacial lake known as Spring lake or Robinson's pond. This lake which is the source of one branch of Steel's brook, a stream lined along the lower part of its course by steep hills, is well toward the top of the highest hills and flows southeasterly and enters the Delaware river at Delhi. Just above the lake are thin bedded greenish sandstones which have the finer lithologic structure of the Chemung rather than that of the coarse grained sandstones of the Catskill formation to the east of the Delaware river. Alternating with these sandstones there are thin, greenish, arenaceous shales similar to those of the Chemung formation. There is also, below the highway, a ledge of thin bedded, faintly reddish sandstone which is apparently replacing the greenish gray, colored sandstones of the Chemung. This stratum if followed to the west probably changes to a typical Chemung sandstone, while to the southeast of the Delaware river it becomes a red sandstone with the lithologic appearance of those of the typical Catskill. This gradual merging of the structural characters of the Chemung with those of the Catskill was clearly stated by Darton and shown in the figures illustrating his paper. He also says that the Chemung formation is "overlain by several thousand feet of hard, coarse, crossbedded gray sandstones with intercalated red shales and gray flags into which they merge eastward and at the expense of which they expand westward. This merging was studied with great care and it was found that stratigraphic continuity throughout is beyond question There is no overlap or wedging out of the beds either as a whole or singly but a gradual transition of coarse materials into fine materials. Lower and lower shaly beds are successively involved eastward till at a point about due south of Oneonta the lowest

beds of shale finally merge into hard, coarse grained, cross-bedded gray sandstones.'[a]

Directly above the highway is a five-foot ledge of thin, greenish sandstone, showing some crossbedding, which resembles the Chemung of the western part of Delaware county. About 20 feet of these sandstones which are partly covered are shown opposite the southern end of the lake. The grains of sand are noticeably finer than in those sandstones near the same stratigraphic position on the southeastern side of the Delaware river. This lake and the rocks about it are near the central part of the area colored as Chemung on the *Geologic map of New York*. At the western side of the highway opposite the house of Mr George Young and the lake is a most interesting exposure of about seven feet of shales, the base of which is 20 feet above the level of the lake. The section is as follows:

SPRING LAKE SECTION

60′		Summit of hill on highway	
	33′+	Covered	
$26\frac{1}{3}$′			
	3′	Thin bedded sandstones to coarse, arenaceous shales	Fossils
	$2\frac{1}{6}$′	Green argillaceous shales	
	$1\frac{1}{2}$′	Red argillaceous shales	
20′		Highway level	
	20′	Thin, greenish sandstones partly covered	
		Level of Spring lake, 720 feet above Delhi	

This outcrop is a very interesting one for above a thin stratum of red, argillaceous shale, green shales occur and above these,

a Am. jour. science, 3d ser., 45: 204-5. See fig. 1 on p. 204 and fig. 2, section B on p. 205 for a diagrammatic representation of the merging of the structural conditions of the Chemung into those of the Catskill.

shales that are coarser; both of which contain quite a good many fossils which are unquestionably in place. *Spirifer mesastrialis* Hall is common in both divisions of the fossiliferous shales associated with Chemung Lamellibranchs. The fauna is:

1	*Spirifer mesastrialis* Hall	(c)
2	*Orthonota* (?) *parvula* Hall	(r)
3	*Ptychopteria* sp.	(a)
4	*Leptodesma* sp.	(rr)
5	*Lyriopecten priamus* Hall	(r)

This outcrop shows clearly enough the survival of a few species of the Chemung fauna, after the appearance of the lower red shales, on the return of the conditions under which the Chemung rocks were deposited.

Along the Delhi highway from Spring lake to the southeast the rocks are generally covered for some 155 feet so that it was not possible to decide upon the line between the Oneonta and Chemung formations. However, one mile southeast of the lake on the road just above the school house of district no. 10 in the southwestern part of Meredith is an outcrop of 15 to 20 feet of red argillaceous shale which is evidently in the upper part of the Oneonta formation. It is probable that this ledge is near the top of the formation since on the other side of the divide the massive greenish sandstone to the southeast of West Meredith is only about 30 feet higher. As far as noticed, from the school house to Delhi the rocks when exposed are the reds and grays of the Oneonta formation. This section has been studied by Mr William L. Fisher, and various other sections in the vicinity of Delhi and the reader interested in the geology of this valley is referred to the following account which he has prepared for this report.

The township of Delhi, in which is located the county-seat of Delaware county, is situated very nearly in the center of the county, on both sides of the west branch of the Delaware river. As will be seen by referring to the map it contains within its borders rocks of three different formations. The southern portion of the township is covered by the Catskill, the northwestern corner is crossed by a narrow belt of Chemung, while the northern part lies within the area of the Oneonta.

The township of Meredith lies just north of Delhi, and as its geologic formation is so much like that of the greater part of Delhi it has seemed best to describe them together. The rocks found in this township are all of the Oneonta formation, except the small area in the southwestern corner which is Chemung.

In this region the first section to be studied is that of Watauga falls and Hall's hill, represented graphically on section 65 E.

Watauga falls are located in a small glen about one mile northeast of the village of Delhi, and are formed by Honest brook just before its junction with the Delaware river. The section in detail is as follows:

30 feet from the river level to the top of the water in the old mill pond. This is mostly covered except for a small exposure of massive sandstone just below the dam.

55 feet of very heavy, red Oneonta sandstone in layers from three to 10 feet thick forming the lowest fall. This rock contains some worm trails, and on the surface of one of the layers is seen a very good specimen of ripple marking.

15 feet, mostly covered, marks the short distance up the brook to the base of the second fall.

42 feet of very fine red shale forms the second fall. A careful search for fossils revealed nothing except one very good specimen of fucoid, a plant about one foot long and showing several branches.

Immediately above this is the third fall of 38 feet, over a ledge the lower part of which is red shale, and the upper part the heavy, red sandstone like the first fall. The surface of some of the shaly layers is sun-cracked, and in the sandstones there are several large pot holes. This sandstone appears as a prominent ledge along both sides of the glen, while the shales below it are nearly covered by the talus slope. Near the base of this sandstone and just above the road was found a small lenticular layer of a very soft, light gray shale. The layer was only a few feet in extent and about two inches thick, and in appearance and hardness much resembled soapstone.

Above the top of this fall the rocks are covered for a distance of 490 feet, or until we approach the summit of the hill known as Round Top, which is just east of the Watauga falls glen.

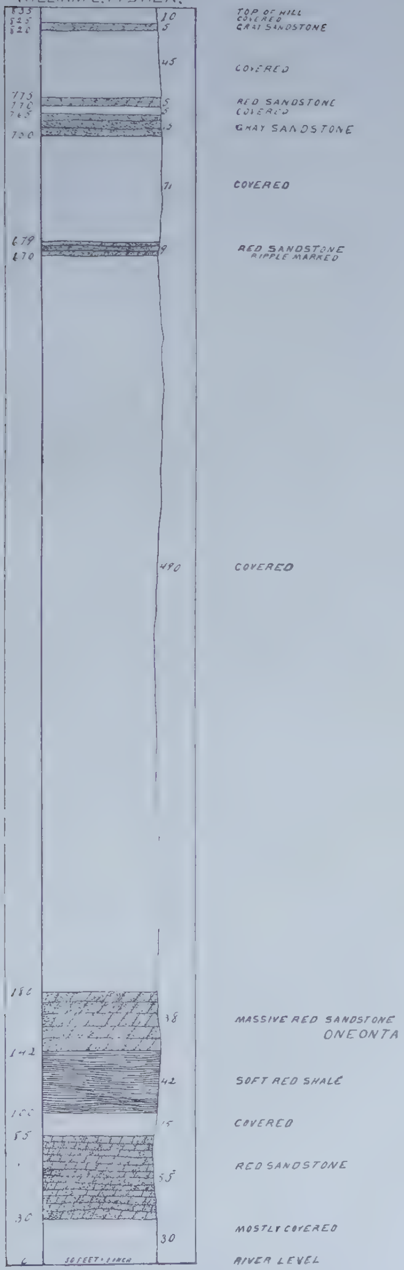
Near the top of this hill is a nine-foot ledge of red Oneonta sandstone showing the best example of ripple marking that has been found anywhere in this region. A few hundred yards farther to the east is a four-foot ledge which seems to occupy very nearly the same position as that just described, but which is composed of gray sandstone instead of red. The sandstone in this ledge is very thin bedded, the layers varying from one fourth to one inch in thickness and in some places they show

No. 65, E. SECTION OF

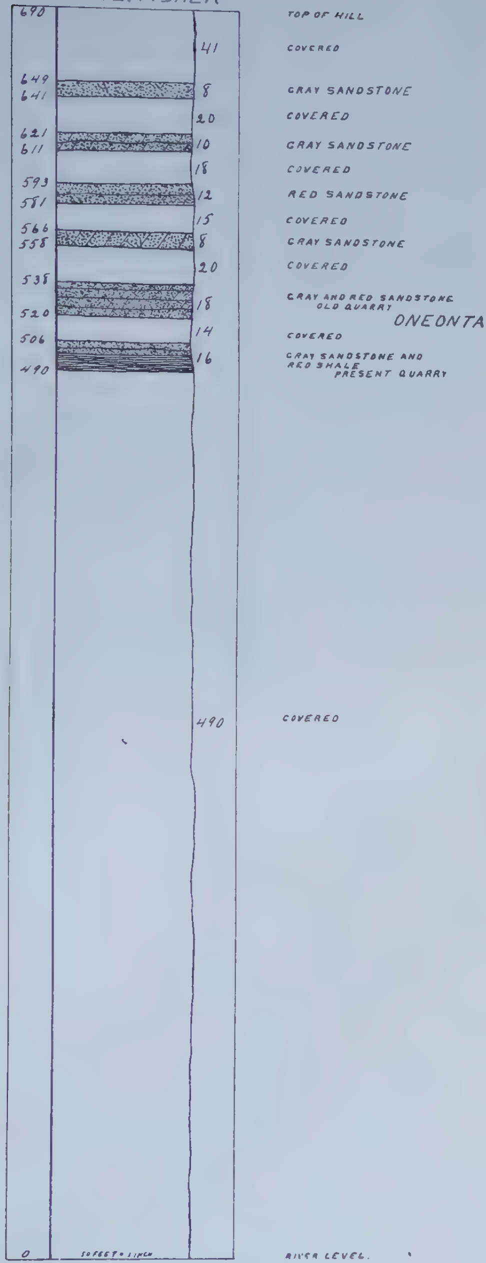
WATAUGA FALLS

AND HALL'S HILL.

WILLIAM L. FISHER.



No. 65. SECTION OF
FISH'S QUARRY
WILLIAM L. FISHER



that very curious crossbedding which is characteristic of the Oneonta, and which is mentioned by both Mather and Vanuxem in the New York state reports[a].

71 feet covered, brings us to a 15-foot ledge of coarse, thin bedded gray sandstone on the hillside just in front of the home of Mr Elmer Hall. This ledge, like all the others on this hill, shows no fossils except occasional fragments of plant stems, but in lithologic character the rocks agree perfectly with the typical Oneonta found in other portions of the county.

Above this ledge there is five feet covered and then a ledge of five feet of red sandstone.

45 feet covered, five feet of gray sandstone, and 10 feet covered brings us to the top of the hill, which is the highest point of ground on the divide between Elk creek and Honest brook.

It will be noticed by referring to the *Geologic map of New York* that Mr Darton claims a large island of Chemung rock covering the top of the hill between these two streams. The island as he represents it should be about four miles long by one mile wide, and at least 200 feet in thickness. A very careful search failed to reveal anything in the nature of Chemung as characterized either by its fossils or by its lithology. The rocks, as indicated by the section, being the coarse red and gray sandstone showing all the features of the typical Oneonta.

From this station a trip was made over onto the hill lying between the east and west branches of Honest brook where Darton claims another island of Chemung; somewhat smaller than the other, but yet about two miles in length. The work here met with the same result as that on Hall's hill, in that it proved that the island of Chemung does not exist. The three small ledges which were found bear unmistakable evidence that the rock is all of the Oneonta formation.

These islands, as well as the four others which Mr Darton represents on his map, must have been placed here simply on account of the altitude of the hills and the supposed stratigraphic position of the Chemung formation, and with no reference to the thinning out of this formation in the western part of the county, nor to its entire disappearance before it reaches Delhi.

The next section is the one called the Fish's quarry section. It starts at the river near Mr D. L. Wight's farm and extends to the top of the hill west of Meredith street in the northern end of the village of Delhi. It will be noticed, by comparing this section with that of 65 E. that the rocks represented in this correspond in elevation to the 490 feet represented as covered between the rocks in Watauga Falls and the lowest ledge on Round

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a Geol. of N. Y. First district. 1843, p. 299. William Mather.
Geol. of N. Y. Third district, 1842, p. 187. Lardner Vanuxem.

Top. By combining these two sections, which are only one half mile apart, we can get a nearly continuous exposure of 800 feet.

The section is as follows:

490 feet covered. This represents the small hill between the river road and the Meredith road, which is partly of glacial origin and in which the rocks are entirely covered with sand, gravel and soil.

16 feet of red shales and gray sandstone in Fish's new quarry. In the red shales in the lower part of the quarry are found numerous sun cracks and some fucoidal markings. On one specimen is a part of a small Lamellibranch shell, but it is too poorly preserved to admit of identification. It is a shell about one fourth inch in diameter shaped somewhat like a *Nucula*, and the surface is ornamented with several quite strongly marked, concentric lines. Its position in the bright red Oneonta shales so far below the base of the Chemung gives it a peculiar interest; and we can only hope that further search in the same region may furnish more specimens from which the species may be identified. The gray sandstone for which the quarry is worked and which is used both for flagging and for building stone, contains large numbers of fragments of plant stems. In some of the layers the surface is almost entirely covered with these fragments, varying in length from one inch to one foot and in width from one line to several inches. Other layers have the surface curiously mottled with large, light gray, clay pebbles.

14 feet, covered.

18 feet, heavy gray sandstone in the old quarry which is now abandoned. Here the sandstone is more massive than in the other quarry, and the plant fragments are more numerous and better preserved.

20 feet, covered.

Eight feet thin bedded, coarse grained, gray sandstone.

15 feet, covered.

12 feet, red sandstone showing worm trails and fucoid markings.

18 feet, covered.

10 feet, gray sandstone. One layer of this sandstone shows some very curious markings on its upper surface. They are rounded pittings varying from one fourth to one half inch in diameter, some of the largest being fully one fourth of an inch in depth. The opposite side of the layer, which is nearly one half inch in thickness, shows a small elevation corresponding to the hollow on the upper surface These markings covered quite a large area in this ledge, and what is probably the same layer was discovered later in a ledge on Van Dyke's hill about one fourth of a mile further east.

20 feet, covered.

Eight feet, gray sandstone. This ledge shows very nicely the curious crossbedded appearance, called by Vanuxem the "oblique laminae of deposition." The layers which are all about one half inch in thickness appear to dip in three or four different directions all in the same ledge.

41 feet, covered, brings us to the top of the hill, and to the end of the section.

From this point the top of this ridge of hills, between Honest brook and Steele's brook was followed as far as Meredith. Darton claims this entire distance to be covered by Chemung, but the most careful search failed to reveal a single Chemung fossil, and the only outcrops which appeared along the route were five small ledges of typical Oneonta shales and sandstones.

The top of the big round hill just west of the village of Meredith is capped by a three-foot ledge of gray sandstone, which is in lithologic character far removed from the fine grained Chemung which the *Geologic map of New York* says should be found in this region.

Federal Hill, no. LXVA, is situated on the southeast side of the Delaware river, just above the village of Delhi. The section starts from the level of the river just above the dam, and runs in a nearly straight line to the place where the old wood road crosses the top of the mountain at a point directly opposite the home of Mr William H. Fisher. The measurements for this section were all taken with a Locke level, and so are more accurate than those of either of the others.

The section in detail is:

121 feet, covered.

34 feet, a conspicuous ledge of red shale capped by gray sandstone layers. This ledge is near the bottom of the hill, just behind the house owned by Mr Thomas Farrington, and the sharp contrast of color between the shales and sandstones makes it a very striking feature of the landscape.

117 feet, covered.

32 feet, red shales and red sandstone ledge.

60 feet, covered.

12 feet, gray sandstone ledge. This ledge contains also a small lenticle of soft, lumpy, gray shale, about four inches in thickness.

53 feet, covered.

Nine feet, thin bedded, coarse grained, gray sandstone.

33 feet, covered.

10 feet, massive red sandstone.

145 feet, covered.

20 feet, gray sandstone. This ledge forms quite a conspicuous

terrace near the top of the hill, and can be traced for quite a distance.

90 feet, covered.

16 feet, massive red sandstone. This ledge forms the top of the hill at this point, although a little farther toward the south the mountain rises some 50 feet higher.

It will be noticed, by referring to the maps, that the top of this section is very near to the line between the Oneonta and the Catskill. However it seems best to regard the rocks here described as being entirely of the former formation, and to consider that this ledge of red sandstone is very nearly if not quite the upper member of the Oneonta formation. This Oneonta-Catskill line can be only an arbitrary one as in this region the rocks are so nearly identical in their lithologic characters as to be quite indistinguishable.

This same line of hills was crossed at three other places in this vicinity, namely, at East Delhi about two miles farther toward the northeast, at Delhi village about one fourth of a mile south, and at Scotch mountain three miles to the south. The sections show such great similarity that it seems unnecessary to describe the other three fully. The rocks are all of the typical Oneonta, the shales being red and soft, while the coarse grained, gray sandstones in thin layers, and presenting the curious crossbedded appearance, belong, very certainly, to this formation.

Mr Darton claims a narrow belt of Chemung, as capping the hills on the eastern side of the Delaware river in this region, and extending eastward into the adjoining counties. He says that the Chemung is "here represented by a heavy mass of coarse, gray, crossbedded sandstones with flaggy layers. Its thickness averages about 250 feet." But as there are to be found no traces of Chemung fossils in this region; and as it is impossible to identify any considerable thickness of the gray sandstone which does not show intercalated beds of red sandstone and shales, it seems better to consider that the Chemung has entirely disappeared, and to regard the Catskill as lying directly upon the Oneonta.

William L. Fisher

The rocks seen along the Delaware river across Delhi township are mostly red shales and sandstones with some gray or greenish gray rocks. They apparently belong in the Oneonta formation as they are represented on the *Geologic map of New York*. Col. Jewett stated that Mr Way collected Chemung fossils at Delhi[a]

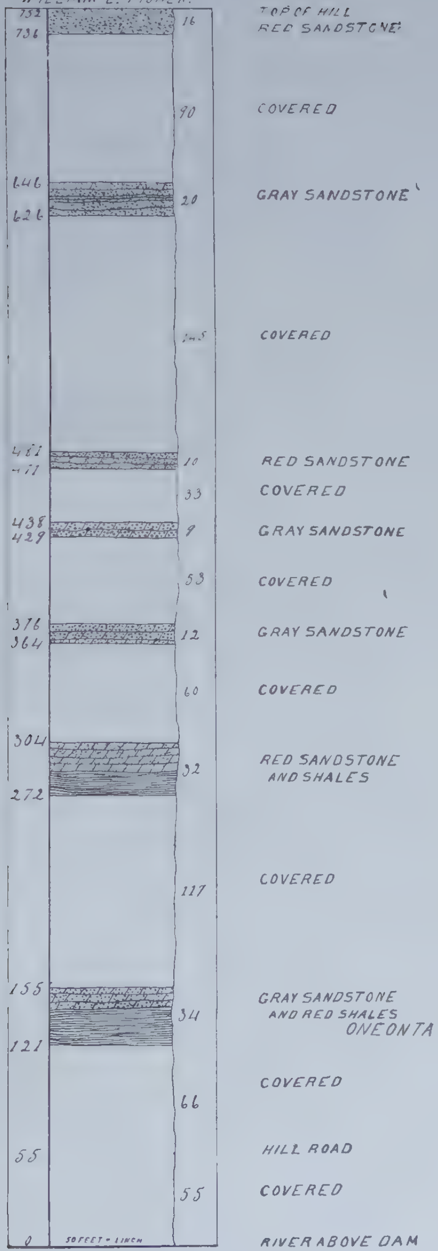
[a] 15th an. rep't regents on State cabinet of natural history, 1862, p. 198. Also in Am. jour. science, 2d ser., 24. 418.

No 65, A. SECTION OF

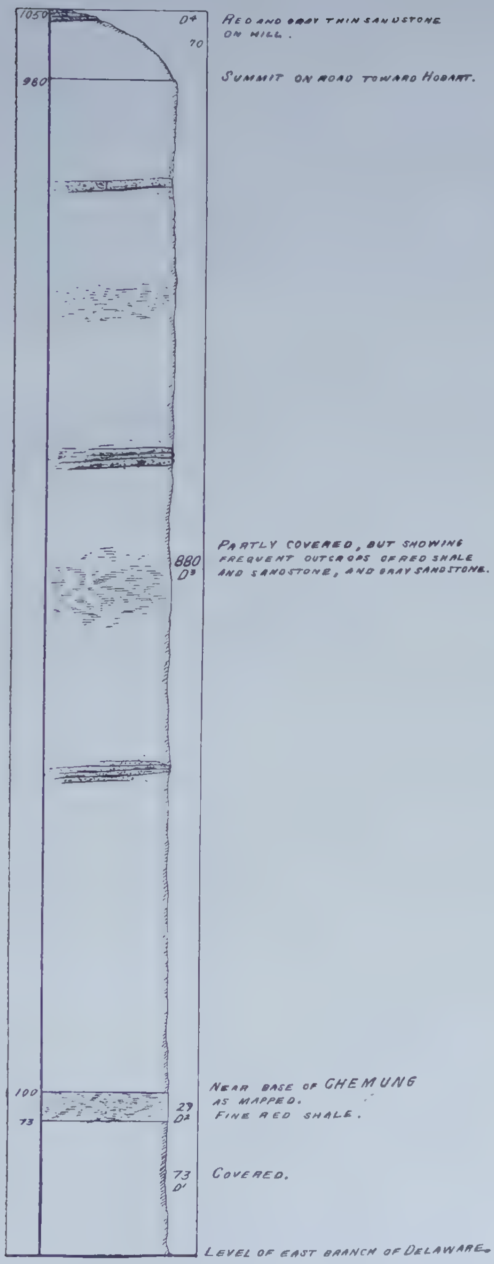
FEDERAL HILL.

ABOVE DELHI

WILLIAM L. FISHER.



No. 64, D. SECTION
NORTHWEST OF
ROXBURY.



but we were not fortunate enough to find any in place although some were found loose along the tributaries of the Delaware below this village.

Along the lower course of the Holmes Hollow brook, one mile above Delancey, in the eastern part of Hamden and western part of Delhi townships are loose pieces of bluish shales containing some fossils as *Liorhynchus*, large and small Crinoid stems and an occasional other specimen. Some rather calcareous pieces contain very poorly preserved specimens of a large *Spirifer*. The list is:

1 *Chonetes scitula* Hall
2 *Liorhynchus mesacostalis* Hall
3 *Orthoceras* sp.

These loose pieces may be from ledges along this valley and of Chemung age. They are hardly rounded enough to have been transported any considerable distance by water. Unfortunately, the slopes of the steep hills lining this narrow valley are covered by drift almost to their tops so that there is not much opportunity to hunt for these fossiliferous shales in place. On the northern side of the brook near the western line of Delhi township, about 400 feet higher than the river road is a thin bedded, coarse grained grayish to greenish gray sandstone, (LXVB^2) with an exposure of 16 feet. In the field below these ledges are large blocks of loose reddish sandstone. Then about 75 feet are covered when another ledge of thin bedded gray sandstone 29 feet thick is reached. Above for 45 feet it is apparently red shale mostly covered and this is capped by a ledge of gray sandstone some 25 feet in thickness. For the next 70 feet the rocks are covered, then a ledge of thin bedded, gray sandstone five feet thick occurs near the summit of the hill on which are numerous blocks of unworn red sandstone. The rocks just described forming the upper part of this hill are represented on the *Geologic map of New York* as in the Chemung formation but their texture and general lithologic appearance are similar to those of the lower part of the Catskill formation in the eastern part of Delaware county. This section may be represented by the following diagram:

SECTION OF HOLMES HOLLOW BROOK

LXV B

Elevation	Thickness	Description	Division	
		Near summit of hill		
	5′	Thin bedded gray sandstone Loose blocks of red sandstone	B⁴	Catskill (?)
660′	70′	Covered	B⁴	Catskill (?)
590′	25′	Gray sandstone	B⁴	Catskill (?)
565′	45′	B^3 Red shale, mostly covered		
520′	29′	Thin bedded gray sandstone	B²	
491′	75′	Covered	B²	
416′	16′	Greenish gray to gray sandstone	B²	
(?) 400′		Loose blocks of red sandstone		
	400′	B^1 Covered. *Chemung* (?)		
0′		Delaware valley road		

Along Bagley's brook east of Delancey (formerly Lansingville) a few fossils were found in loose pieces of shale similar to those in the Holmes Hollow brook:

1 *Spirifer mucronatus* Con.
2 *S. mesastrialis* Hall
3 *Sphenotus contractus* Hall
4 *Microdon* (*Cypricardella*) *tenuistriatus* Hall

The lower slopes of the hills along this stream are also covered by soil, drift and gravel so that there is no opportunity to examine the bed rocks. Higher in the hills are red and gray sandstones and shales.

LXV A. On the eastern side of the Delaware river to the northeast of Delhi is a steep hill known as Federal Hill. Along the Federal Hill road from the Delaware valley road nearly to its summit are frequent ledges of red sandstone and shales alternating with grayish sandstones. Near the summit of the road is more of the gray sandstone below which the rocks are prevailingly red. In the field on the south side of the road, about 65 feet above the base of the coarse gray sandstone exposed on the road near its summit, is the top of a ledge of thick, gray sandstone. However, there is a zone of red between the top and bottom of this mass of gray sandstone. On the *Geologic map of New York* the Oneonta sandstone is represented well toward the summit of Federal Hill, which is apparently correct, but its top is mapped as capped by Chemung.

On the hill south of the Delaware river in the western edge of Stamford township, opposite Bloomville, are quite thick ledges of sandstone near the boundary line between the Oneonta and Chemung formations as represented on the *Geologic map of New York*. First there are ledges of about 40 feet of greenish gray, coarse grained sandstone. In the lower part of these sandstones are specimens of *Rhodea pinnata* Dn., which are common in one place. Succeeding the gray sandstones are those that are reddish and thin bedded, at least 35 feet thick with a layer of gray sandstone about 20 feet above their base. Then the rocks are

covered for about 14 feet when a ledge of massive, quite thick bedded, gray sandstone, from eight to 10 feet thick, occurs and this is capped by red sandstone. With the exception of the plants no fossils were found, and the rocks more nearly resemble the Oneonta or Catskill than the Chemung.

On the hill to the south of Almeda, a station about half way between Hobart and Bloomville on the Ulster and Delaware railroad there is, for about 80 feet from the railroad, for the most part soft, argillaceous shale; then a ledge of coarse, greenish gray sandstone is reached which is about 35 feet thick. Above, the rocks are partly covered, but there are quite frequent exposures of red shales and sandstones which extend nearly to the top of the hill, 180 feet higher. The top of this hill to the north of Rose's brook is apparently in the Chemung formation as colored on the *Geologic map of New York*. Again, the dividing line between the Oneonta and Chemung is represented as running near the clove road south of Hobart. On this road near the head of the clove is a bank of soft red shale 10 feet in thickness. On the clove road and bank of the brook some 130 feet lower than the red shales are coarse, grayish, irregular bedded sandstones between red shales. The upper part of the ledge is coarse grained red sandstone with the same texture as the gray sandstone. There are layers of breccia with clay pebbles, slightly calcareous, but no fossils were found. There is so much red shale in this vicinity that the roads and fields are colored red from it and it makes a fertile country. These outcrops south of Almeda in Stamford township and along the clove road seem to be in the Oneonta sandstone.

Roxbury

To the east of Stamford township and the upper valley of the Delaware river is Roxbury, the most eastern township of Delaware county. It is crossed from the north to the south by the east or Pepacton branch of the Delaware river which is lined on both sides by steep hills or mountains. On the *Geologic map of New York* the river valley and the lower slopes of the hills are

VIEW DOWN ROSE BROOK VALLEY TOWARD THE DELAWARE RIVER, SOUTH OF ALMEDA

represented as in the Oneonta sandstone, while the higher part of the hills is colored as in the Chemung formation. There are fair outcrops along the highways crossing these hills, both to the east and to the west of the river, which afford a ready means for comparison between them and the Chemung rocks in the western part of Delaware county and along the Susquehanna valley.

LXIV D. One of the best section noted for such comparison is the one along the Roxbury and Hobart highway across the high hill to the northwest of Roxbury. This section is shown diagrammatically in another part of this report; but it is of sufficient importance to merit a more detailed description. From the bridge level over the east branch of the Delaware at Hubbell corners for some 73 feet the rocks are covered; but where the road forks for Hobart and Bloomville, and lower toward the brook there is an outcrop (D^2) of 27 feet of red argillaceous shale. On the *Geologic map of New York* the line of separation between the Oneonta sandstone and Chemung formation is represented as crossing the road at this fork. From this fork to the summit of the hill on the road is barometrically 880 feet, and along the highway there are numerous outcrops of red sandstone and shale alternating with gray sandstone; also layers of breccia both red and greenish gray in color containing fragments of fish bones. On the hill south of the highway and 70 feet above the road summit are ledges of gray and red thin bedded sandstones some of which have very much crossbedded structure. On the *Geologic map of New York* the rocks from the Bloomville-Hobart fork up to the summit and down the western divide are colored as in the Chemung, while the base of the Catskill is represented near the top of the high hill south of the road summit. This would give at least a thickness of 900 feet for the Chemung on this hill. In this section it is difficult to recognize any of the characters of the Chemung of the western part of Delaware county and apparently, about the same lithologic characters extend from the Oneonta sandstone along the river valley to the top of the high hill, and it seems to the writer that the conditions under which the Catskill was deposited have about replaced those of the Chemung.

In using the name Catskill formation the writer does not wish to be regarded as considering the rocks of this formation later in age than the Chemung for it is perfectly evident to him that at least the lower part of the formation and perhaps all of it is synchronous with the Chemung as found farther west in southern New York. There can be no question but that the Chemung merges into the reds and grays of the Catskill as they are followed eastward from the Susquehanna valley. The term Catskill formation, however, is a convenient name for the great mass of red and gray sandstones, shales, and conglomerates found in the Catskill mountain region and is used in this sense in the present report.

The steep hill to the southeast of Roxbury forming the divide between the Batavia kill and the east branch of the Delaware was crossed. The section is along the first east road south of Roxbury which follows a small brook at the northern end of Whortlebury mountain.

SECTION SOUTHEAST OF ROXBURY

765′		C^6 Red shales on summit of road 725′ Block of red shale on road
595′	170′	C^5 Covered Red and gray sandstones and shales
495′	100′	Partly covered C^4
115′	380′	Mostly covered C^3 Greenish gray coarse sandstone and reddish sandstone
0′	115′	C^2 C^1 Covered Level of river road, perhaps 50 feet above the river

The lowest ledge in the above section (C^2) shows large blocks of coarse, greenish gray and red sandstone some of which are

in place and others not. There are layers of breccia with clay pebbles but no fossils were found. In C⁴ there are red shales below, then coarse grained gray sandstone which is reddish above, and the upper 45 feet as far as exposed is red sandstone. There are algoid stems in the coarse red shale but no other fossils were found. The upper part of the hill (C⁶) is apparently all red argillaceous shale, some of which is of blocky structure, showing on the main Roxbury road about 40 feet below the summit of the hill. On the *Geologic map of New York* the Oneonta sandstone is represented along the lower part of the hill while above this and reaching its summit is the Chemung formation. As is seen from the above section in the upper 270 feet of the hill red shales and sandstones apparently predominate.

Through the pass between Roxbury and Grand Gorge the coarse greenish gray sandstones, and red shales and sandstones of the Oneonta formation are well shown.

On the hill about one mile north of Grand Gorge (formerly Moresville) on the northern side of the Bear kill in the southern part of Gilboa township, is the following section in the Oneonta sandstone.

SECTION NORTH OF GRAND GORGE

LXIV B

320′		Top of hill
	35′	B^4 Gray coarse bedded sandstones forming a massive ledge 10 feet thick at the base
285′		
	20′	B^3 Covered
265′		
	40′	B^2 Thin bedded grayish sandstone, irregularly bedded and forms massive ledge
225′		
	225′	B^1 Gray sandstones and shales alternating with red to creek level. Partly covered
0′		Level of the Bear kill

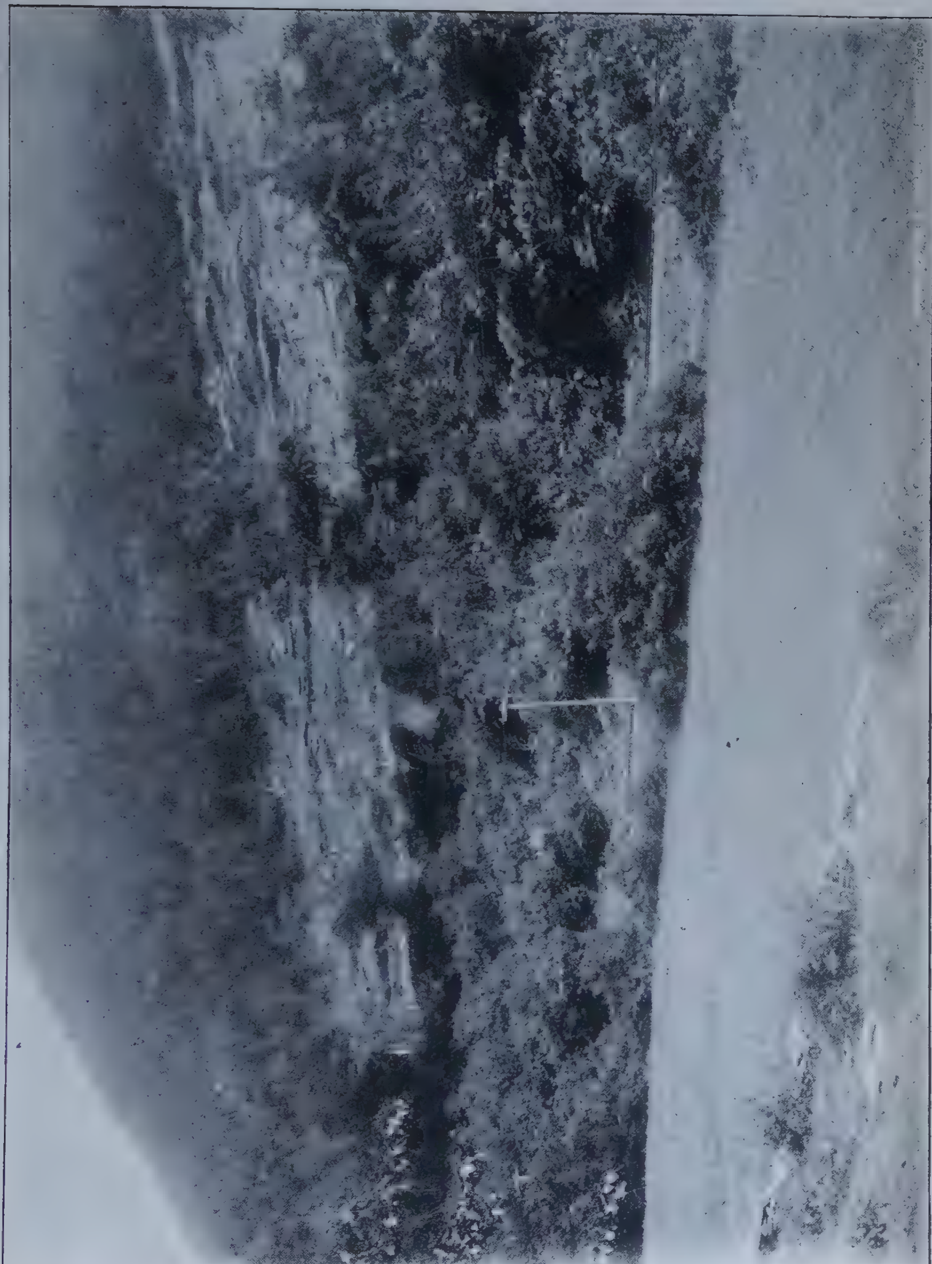
No fossils were found in the above section or in any of the exposures examined in the vicinity of Grand Gorge. The red shales and sandstones of the Oneonta are conspicuous in the hill southwest of Grand Gorge and the rocks in the vicinity of the village are represented on the New York map as near the middle of the formation which according to the generally understood limits of the Oneonta formation seems to be about their stratigraphic position.

CHARLOTTE VALLEY SECTION

The Charlotte river rises in the northwestern part of Summit township, Schoharie co., and flows generally in a southwesterly direction across the northern part of Delaware co., entering the Susquehanna river at Emmons, above Oneonta. To the north of the river is a steep range of hills across the southeastern part of Otsego co. separating its valley from that of Schenevus creek, while to the south is a wider divide between the Charlotte and Delaware river valleys. The rocks along the immediate river valley belong mainly in the Ithaca formation while part of the steep hill to the north is capped by the Oneonta formation which forms, very largely, the northern slope of the hill on the south.

Davenport

Davenport is one of the northern tier of townships in Delaware co. bounded on the north by Maryland and Oneonta township of Otsego co., and on the west by Franklin. The Charlotte river crosses the township from its eastern border nearly to its western line and receives a number of branches; the larger ones from the south. The slopes of the hills are pretty well mantled with drift, and no very extensive sections were discovered during the hasty examination which it was possible to give the township. In general, however, it was determined that along the river valley the rocks belong in the Ithaca formation; while the upper part of the steep hill to the north along the Davenport-Maryland township line is capped by the Oneonta which extends considerably farther northeast than is represented on the *Geologic map of New York.*



On the hill north of the Charlotte river, northeast of Davenport Center, at an elevation of some 166 feet above the river level are ledges of bluish shales (LXXII C²) containing Ithaca fossils. About 60 feet higher are large, loose blocks of the Oneonta sandstone which caps the hill and have probably rolled down from it. On the north side of the river, about three fourths of a mile northeast of Davenport, almost opposite the mouth of Middle brook, and nearly 70 feet above the river road are ledges of bluish shales (LXXII A²) in the Ithaca formation from which the following four species were obtained as the result of a few minutes search:

1	*Actinopteria boydi* (Con.) Hall	(a)
2	*Chonetes setigera* Hall	(r)
3	*Camarotoechia stevensi* (Hall) H. & C. (?) Imperfectly preserved.	(rr)
4	*Phacops rana* (Green) Hall	(rr)

One fourth of a mile northeast of Fergusonville, by the side of the highway, there is an exposure of 15 feet of bluish shales and sandstone (LXXIIB²). The rocks belong in the Ithaca formation; but are not very fossiliferous. Specimens of *Liorhynchus mesacostalis* Hall and *Microdon* (*Cypricardella*) *gregarius* Hall were obtained.

Along a small brook, a northern branch of Middle brook, in the northeastern corner of Kortright township about three miles southeast of Davenport, are bluish shaly sandstones (XXXII A²) containing fossils. Those found were:

1	*Spirifer mesastrialis* (Hall)	(c)
2	*S. mucronatus* (Con.) Bill.	(c)
3	*Tropidoleptus carinatus* (Con.) Hall	(rr)

The outcrop is perhaps one half mile above the valley road along Middle brook and the rocks are in the Ithaca formation. The hill to the north of Middle brook in the northeastern corner of Kortright and southeastern corner of Davenport was examined, some 385 feet higher, near its summit and the general elevation of the highest land of that region. Toward the upper

part of the hill only ledges of gray, thin bedded sandstone were seen in place. Some of the grayish sandstone shows fine examples of oblique bedding. Near the top of the hill part of the sandstone is of greenish gray color and a specimen was found containing *Amnigenia catskillensis* (Van.) Hall, which apparently came from one of the greenish layers. On the surface is an abundance of loose, red rock which must have formerly capped the hill, but none was found in place. Mr Fisher has given some time to the study of the geology of the southern part of Davenport and he has kindly contributed the following notes:

The townships of Davenport and Harpersfield form the extreme northeastern portion of Delaware county. The country is hilly, but the hills are neither so high nor so steep as those in the more central and eastern part of the county. They are drained by the Charlotte river and its branches, the river itself being a tributary of the Susquehanna.

The low ground in the valley of the Charlotte, and the bases of the hills on either side of it, are made up of rocks of the Ithaca formation. The tops of the hills are capped with the heavy sandstones of the Oneonta formation.

The lower part of the valley, between West Davenport and Davenport Center, was searched pretty carefully, but very few exposures of rock in place were found. The country is very largely covered with drift and soil, so that even the deeper cuts along the line of the Cooperstown and Charlotte Valley railroad expose only thick beds of sand and coarse gravel. The loose stones found along the roadsides and in the bed of the creek, which are greenish gray shales and soft gray or brown sandstone, are very fossiliferous, and from these loose pieces the following Ithaca fossils were collected.

1 *Nucula corbuliformis* Hall
2 *Nuculites oblongatus* (Con.) Hall
3 *Palaeoneilo plana* Hall
4 *Palaeoneilo emarginata* (Con.) Hall
5 *Palaeoneilo muta* Hall
6 *Palaeoneilo maxima* (Con.) Hall
7 *Microdon (Cypricardella) bellistriatus* Con.
8 *Microdon (Cypricardella) gregarius* Hall
9 *Macrodon hamiltoniae* (?) Hall
10 *Modiomorpha mytiloides* Con.
11 *Grammysia* sp.
12 *Paracyclas lirata* (Con.) Hall
13 *Glyptodesma erectum* (Con.) Hall

14 *Leptodesma rogersi* Hall
15 *Actinopteria boydi* Hall
16 *Pleurotomaria lucina* Hall
17 *Spirifer mucronatus* Con.
18 *Spirifer mesastrialis* Hall
19 *Spirifer tullius* Hall
20 *Spirifer medialis* Hall
21 *Chonetes coronata* Con.
22 *Tropidoleptus carinatus* Hall
23 *Camarotoechia contracta* (Hall) H. & C.
24 Crinoid segments

On the north side of the river the only exposure that was found was one ledge of coarse gray sandstone, 17 feet in thickness, near the top of the hill about one mile east of Davenport Center. In this ledge the sandstone is thin bedded, somewhat diagonally stratified and presents all the features of the typical Oneonta, which is certainly found on the higher part of this ridge of hills.

On the south side of the river the results were a little more satisfactory. Near West Davenport, in a small depression by the roadside, were found some large angular blocks of a soft gray sandstone containing a few fragments of shells. On the hillside, about half way between West Davenport and Davenport Center, is a long low ledge of coarse gray sandstone. This ledge, which is 15 feet in thickness and is situated about 70 or 80 feet above the bed of the river, runs along the face of the hill for a considerable distance. No fossils whatever were found in this rock, which fact, together with its lithologic character, a very coarse, thin bedded, gray sandstone, leads to its classification under the Oneonta formation. From the position of this ledge so near the bottom of the hill, it would seem very probable that it marks the line between the Oneonta and the softer rock of the Ithaca, which has all been worn away and covered by drift.

In the upper part of a small brook which flows into the Charlotte about one half mile below Davenport Center, is an exposure of about 30 feet of heavy red sandstone. This rock forms a series of low falls in the brook just below an old mill dam. This exposure, both from the character and color of the rock, and from its position near the upper part of the hill is very certainly Oneonta.

WILLIAM L. FISHER

Worcester

Worcester is the southeastern township of Otsego co., with Maryland on the west, Westford and Decatur on the north, Summit township of Schoharie county on the east, and Harpersfield

township of Delaware county on the south from which it is separated by the Charlotte river. The Schenevus creek crosses the northern part forming a narrow valley lined by steep hills and in the southern part is the broader valley of the Charlotte river which receives a number of tributaries from the north. Separating the two valleys is a steep and high ridge which extends southwesterly across the southern part of Maryland and the northern part of Davenport and into the eastern part of Oneonta and southern part of Milford nearly to the junction of the Charlotte and Susquehanna rivers. The upper part of this high ridge from its southwestern end northeasterly into the western part of Worcester is composed of the massive greenish gray sandstones of the Oneonta formation. This was so represented on the geologic map published in part 1 of this report; while on the *Geologic map of New York* the Oneonta formation was mapped as occurring only near the summit of the ridge which it followed for about four miles along the Millford-Oneonta and Maryland-Davenport township lines into the western part of the last two townships. There are conspicuous exposures of the massive Oneonta sandstone on the hill south of Schenevus in the southern part of Maryland which were briefly described in the former report[a]. On the hill to the east of the schoolhouse are heavy ledges of the greenish gray sandstone which form typical outcrops of the Oneonta sandstone and there are frequent outcrops of it along this hill to the east. By the highway a little over two miles southeast of Schenevus, red sandstones are exposed below the gray sandstones. This locality is near the Maryland-Worcester line and about 100 feet higher than the base of the Oneonta sandstone at XXII I^4, on the hill south of Schenevus. The Oneonta sandstone extends along the ridge for rather more than a mile into Worcester township, being last seen on the high point near the first road which turns to the south.

XXVI A^3. On the top of the steep hill one and one half miles south of Worcester and 800 feet above the railroad station at

a 15th an. rep't N. Y. state geologist, p. 268, 22 I^4.

Worcester are blue shales containing the Ithaca fauna, *Spirifer mesastrialis* Hall being common, and the upper part of this hill belongs in that formation. The following species were collected:

1	*Spirifer mesastrialis* Hall	(r)
2	*Palaeoneilo emarginata* (Con.) Hall (?)	(rr)
3	*Microdon* (*Cypricardella*) *gregarius* Hall	(c)
4	(?) *Modiomorpha* sp.	(rr)

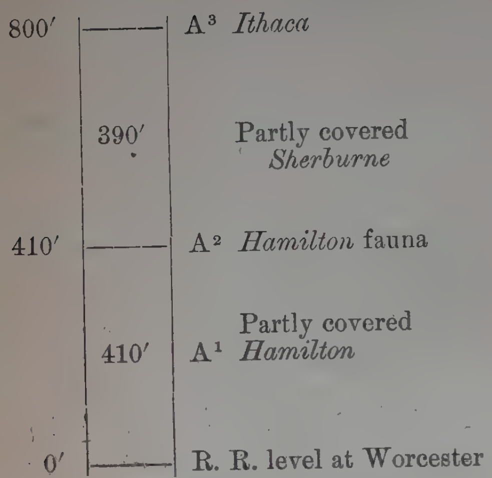
XXVI A^2. Circumstances did not permit a careful examination for fossils in the rocks along the highway down into the valley; but some 390 feet lower than the horizon containing the Ithaca fossils are coarse, bluish, arenaceous shales with an abundant Hamilton fauna. The Hamilton rocks extend above the highway corners where one road turns to the southwest and crosses Schenevus creek nearly two miles below the village. It was not determined whether this zone was about at the top of the Hamilton or not but it is certain that there are over 400 feet of Hamilton rocks in the steep hill south of Schenevus creek at Worcester. In the few minutes spent in collecting at A^2 the following species were obtained:

1	*Spirifer mucronatus* (Con.) Bill.	(r)
2	*S. granosus* (Con.) H. & C.	(rr)
3	*Tropidoleptus carinatus* (Con.) Bill.	(a)
4	*Athyris spiriferoides* (Eaton) Hall	(rr)
5	*Craniella hamiltoniae* (Hall) H. & C. (?)	(rr)
6	*Nucula bellastriata* (Con.) Hall	(c)
7	*Palaeoneilo constricta* (Con.) Hall	(rr)
8	*P. maxima* (Con.) Hall	(rr)

That there was not the opportunity to make a thorough collection from the Hamilton rocks of this hillside is a matter of regret for it is apparently an excellent locality at which to obtain a characteristic fauna of the upper part of this formation. The general outline of the section may be represented by the following diagram:

SECTION OF THE HILL SOUTH OF WORCESTER

XXVI A



On the hill south of Schenevus creek two and one half miles about east of Worcester and 700 feet above the creek level is a thin, rather coarse grained sandstone quarry (26B¹). A single specimen of an imperfectly preserved Lamellibranch shell was found belonging either to the genus *Actinopteria* or *Liopteria*. Still higher in the field are more argillaceous, non-fossiliferous shales and more argillaceous sandstones which together with the sandstones of the quarry belong in the Sherburne formation. The line of division between the Hamilton and Sherburne formations may be followed along the side of the steep hill south of Schenevus creek nearly to the schoolhouse at the four corners in district no. 15, toward the head of Multer creek[a], nearly two miles southwest of East Worcester. Then the line turns nearly to the south and follows the hill on the western side of Multer creek through Center valley, crossing it near the center of school district no. 13. The line next runs to the north and then south across the ridge east of Multer creek, makes a loop on the hill to

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[a] No name was found on the maps for the largest tributary of the Charlotte river from the north between South Worcester and Charlotteville and the name Multer creek is proposed for it on account of the presence of several families of that name in the lower part of its valley.

the north of Charlotteville in Summit township, Schoharie co., and crosses to the south side of the Charlotte river a little below the village and then continues along the side of the hill on the south side of the river northeasterly toward Summit village.

XXVI B². Along the highway in the upper part of Multer creek, district no. 15, about two miles southwest of East Worcester are blue argillaceous shales containing Hamilton fossils and the rocks belong in that formation. This exposure is only a short distance above the road corners and the schoolhouse. The following species were collected:

1 *Tropidoleptus carinatus* (Con.) Hall	(a)
2 *Vitulina pustulosa* Hall	(c)
3 *Spirifer mucronatus* (Con.) Bill.	(r)
4 *Nucula corbuliformis* Hall	(c)
5 *Nuculites triqueter* Con.	(r)
6 *Macrodon hamiltoniae* Hall	(rr)

XXVI B³. On top of a high hill three fourths of a mile south of East Worcester are blue argillaceous shales in the upper part of the Hamilton formation. This locality is about one and one half miles northeast of B² and approximately 240 feet higher. The fossils are as follows:

1 *Spirifer granosus* (Con.) H. & C.	(rr)
2 *S. mucronatus* (Con.) Bill.	(rr)
3 *S. tullius* Hall (?)	(rr)
4 *Vitulina pustulosa* Hall	(r)
5 *Tropidoleptus carinatus* (Con.) Hall	(c)
6 *Nuculites triqueter* Con.	(rr)
7 *Hyolithes aclis* Hall	(rr)

XXVI B⁴. On the highway leading into East Worcester, 85 feet below B³, is a fair exposure of the blue argillaceous shales of the Hamilton which are quite fossiliferous, the following species having been collected during a few moments' search:

1 *Spirifer mucronatus* (Con.) Bill.	(c)
2 *Tropidoleptus carinatus* (Con.) Bill.	(c)
3 *Chonetes coronata* (Con.) Hall	(c)

4 *Nucula bellistriata* (Con.) Hall (c)
5 *Nuculites triqueter* Con. (rr)
6 *Palaeoneilo constricta* (Con.) Hall (rr)

XXVI C[1]. On the hill west of Multer creek, about one and one half miles below Center Valley schoolhouse, is a small quarry in rather coarse grained, thin bedded, bluish sandstones similar to those on top of the hill south of Worcester and stratigraphically apparently in the Sherburne formation. This formation becomes more arenaceous as it is traced eastward and forms thin flags. Fossils are rare although the few found indicate the lower Ithaca formation to which, perhaps, these rocks should be referred rather than to the Sherburne. The list is:

1 *Spirifer mucronatus* (Con.) Bill. (r)
2 *S. mesastrialis* Hall (?) (rr)
Broken and imperfectly preserved.
3 *Tropidoleptus carinatus* (Con.) Hall (rr)
4 Lamellibranch shell (rr)
5 Fragments of wood

XXVI C[2]. With the exception of some rather steep cliffs toward South Worcester the hill on the north side of the Charlotte river between South Worcester and the Multer valley is largely covered by soil. Rather more than one mile east of South Worcester near the top of the hill 450 feet above the river road are loose, unfossiliferous, shaly sandstones, and some about in place that contain Ithaca fossils, as follows:

1 *Spirifer mesastrialis* Hall (?) (rr)
Very imperfectly preserved.
2 *Microdon (Cypricardella) gregarius* Hall (c)
3 *Palaeoneilo plana* Hall (rr)

On the lower part of the steep hill about 90 feet above the highway nearer South Worcester is quite a prominent ledge of bluish shales. There are a few fossils, *Tropidoleptus carinatus* (Con.) Hall being the most abundant. This looks like the transition zone from the Sherburne to the Ithaca formation. About

100 feet higher on the hill are plenty of loose blocks, apparently from higher ledges, containing an Ithaca fauna.

XXVI D. On the western side of the brook valley, one and one half miles north of Charlotteville, or about four miles south of East Worcester is an interesting section in the upper Hamilton which follows the cross road west of the brook valley at the "First baptist church of Summit" and is near the township line between Summit and Worcester. About 107 feet above the level of the valley road by the side of the cross road are soft, blue, argillaceous shales (D^2) containing an abundance of Hamilton fossils. The list is as follows:

1	*Spirifer mucronatus* (Con.) Bill.	(c)
2	*S. tullius* Hall	(rr)
3	*S. granulosus* (Con.) H. & C. (?)	(rr)
	Very poorly preserved.	
4	*Tropidoleptus carinatus* (Con.) Hall	(r)
5	*Leda rostellata* (Con.) Hall	(rr)
6	*Schizodus appressus* (con.) Hall.	(rr)
7	*Chonetes setigera* Hall	(rr)
8	*Palaeoneilo maxima* (Con.) Hall	(r)
9	*Nucula bellistriata* (Con.) Hall	(c)
10	*Nucula corbuliformis* Hall	(rr)
11	*Nuculites oblongatus* Con.	

About 50 feet higher is the Aaron Silvernaile quarry (D^3) where some eight or nine feet of blue, flagging stone is shown. The sandstone splits into layers from one and one half to four inches in thickness and the quarry has been worked to a considerable extent for flagging stone. Above the sandstone are shaly layers in which fossils are fairly common. The species listed below were collected on the dump heap of the quarry:

1	*Spirifer tullius* Hall	(a)
	Abundant in thin layers.	
2	*S. mucronatus* (Con.) Bill.	(c)
3	*S.* sp.	(rr)
	Very poorly preserved; perhaps *S. granulosus* (Con.) H. & C.	

4 *Tropidoleptus carinatus* (Con.) Hall (c)
5 *Glyptodesma erectum* (Con.) Hall (r)
6 *Grammysia bisulcata* (Con.) Hall (r)
7 *G.* *(Sphenomya) cuneata* Hall (rr)
8 *Modiomorpha subalata* (Con.) Hall (?) (rr)
9 *Palaeoneilo constricta* (Con.) Hall (rr)
10 *Pleurotomaria sulcomarginata* Con. (?) (rr)
11 *Planolites clarkii*, sp. nov. (c)

This quarry is referred to the Hamilton formation although near its summit, for it is thought that the top of the hill is in the base of the Sherburne formation. A view of the wall of this quarry and another of the dump heap were given in part 1 of this report on plates 7 and 8.

SECTION OF HILL AT SILVERNAILE QUARRY

220′		Top of hill	
			Sherburne (?)
	55′	D^4 Covered	
165′			
	8′	D^3 Silvernaile quarry	
157′			
			Hamilton
	50′		
107′		D^2 Shales with Hamilton fossils	
	107′	D^1 Covered	
0′		Level of road in valley	

ANNELIDA

PLANOLITES Nicholson, 1873, *Proc.* Roy Soc., London, p. 289

Planolites clarkii nov. sp.

Horizontal, tortuous, and undulating burrows or tracks which are simple, rounded furrows of about equal width throughout their length. One undulating track is 26 cm in length and 4 mm in breadth; while some of the very tortuous ones are considerably longer, as for example one is 59 cm and 5 mm in breadth. The greater part of the burrows is not filled and is smooth. In the better preserved portions of some of the trails, however, are somewhat imperfect transverse parallel furrows and ridges, one specimen having 18 in the space of 1 cm. The ridges are broader than the furrows, varying from one half to three fourths of a mm in width. These furrows and ridges apparently represent the segments of the worm. Other portions of the burrows are filled with cylinders of arenaceous material, not especially different from the matrix, which have a smooth surface and show no structure. This filling is probably the sand that was passed through the alimentary canal of the worm, although it is possible that they are simply casts of trails as have been described by Nathorst. As far as noted these burrows were all in the lamination planes of flagstone strata.

These tracks somewhat resemble *Gyrichnites gaspensis* Whiteaves[a] from the Lower Devonian (Gaspé sandstones) of Gaspé Bay, Quebec, but they are much smaller and not marked by the conspicuous grooves of that species.

A specimen was submitted to Prof. Whiteaves who wrote as follows: "Your specimen shows parts of the arenaceous filling of the burrow or mold, if it is an annelid track, and clearly differs from the Gaspé species of *Gyrichnites*, as you say, by its much smaller size. In your specimen, also, there seems to be somewhat greater rigidity, and a closer disposition of the transverse annulations.

It is not at all easy to make up one's mind as to whether your tracks should be regarded as referable to *Planolites* or to *Gyrichnites*. For, although the convex filling of your specimen is no

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[a] Trans. roy. soc. Canada, sec. IV, 1882, p. 109, pl's XI, XII.

doubt scarcely distinguishable from *Planolites*, yet the concave portion, into which it fits, is tranversely and closely annulated, as it were, or at any rate shows transverse markings, a feature which is not indicated nor figured in Nicholson's diagnosis and figure of *Planolites*. In this latter respect, no doubt, your specimens agree better with *Gyrichnites*, but they may, also, indicate a generic type different from either that genus or *Planolites*."

In regard to the transverse markings it is to be remembered that *Planolites annularis* Walcott from the Cambrian of Washington co. N. Y., "shows numerous annulations."[a]

The specimens might also be compared with *Protoscolex ornatum* Ulrich;[b] but that species has much shorter and slenderer tracks with much narrower segments.

Locality: Silvernaile quarry, Worcester township, four miles south of East Worcester and one and one half miles north of Charlotteville.

Geological horizon: Near top of Hamilton formation.

XXVI E¹. On the valley road toward East Worcester and about one half mile north of the "First baptist church of Summit" are bluish, argillaceous shales containing plenty of fossils.

This is a typical exposure of the soft Hamilton shales and the following fossils were found:

1	*Spirifer tullius* Hall	(rr)
2	*Chonetes setigera* Hall	
3	(?) *Centronella impressa* Hall Imperfectly preserved and difficult to identify.	(c)
4	*Nucula bellistriata* (Con.) Hall Small form.	(a)
5	*Modiomorpha* sp.	(rr)
6	*Leptodesma* sp.	(rr)
7	*Liopteria dekayi* Hall	(rr)
8	*Murchisonia micula* Hall (?)	(rr)
9	*Tentaculites bellulus* Hall	(c)
10	Crinoid segments	(c)

[a] See 10 an. rep't U. S. geol. surv., p. 603, and pl. 60, fig. 5.
[b] Jour. Cincinnati soc. nat. hist., 1878. 1: 90, pl. 4, fig. 1.

Summit

Summit which is one of the western tier of townships in Schoharie co. lies directly east of Worcester. The central part of it is an elevated plateau while in the western part are the upper valley and headwaters of the Charlotte river; in the northern part streams rise that flow northerly into the Cobleskill and in the eastern part streams that flow easterly into the Schoharie river.

As has already been mentioned the line of division between the Hamilton and Sherburne formations crosses the Charlotte river near Charlotteville and follows the northern slope of the valley northeasterly to within, perhaps, one mile of Summit. Then it runs southeasterly along the Westkill into the northern part of Jefferson township where it crosses the stream and then turns northerly along the eastern side of the valley and around the high land east of Summit when it turns easterly and follows the northern slope of the hill south of Panther creek across the southern part of Fulton township into the Schoharie river region.

XXVI X. To the south of Charlotteville and the Charlotte river is a steep hill rising nearly 600 feet above the level of the river, and in the banks below the dam at Charlotteville are blue flagging stones (X^1) forming a ledge some eight feet thick. There are some layers containing plant stems and a few pebbles, and some partings of blue shale. The dip is about 1° S60° W. Along the banks of the river are plenty of loose stone containing Hamilton fossils in abundance and the bed rocks resemble the flagging stones of the upper part of the Hamilton in the southwestern part of Albany co., to which formation this zone is referred.

For 400 feet above the river the hillside is covered when a ledge of massive bluish gray sandstone (X^3) is reached southeast of Charlotteville. The stone splits into thin flags, in places is somewhat crossbedded and about five feet are shown. No fossils were found and it is apparently in the Sherburne formation.

On the top of the hill southeast of Charlotteville 12 feet higher than X^3, and near the Summit-Jefferson township line is a ledge of thin, bluish sandstone to arenaceous shale (X^5) containing fossils, specially *Actinopteria boydi* (Con.) Hall. The complete list is:

1	*Actinopteria boydi* (Con.) Hall	(c)
2	*Palaeoneilo emarginata* (Con.) Hall var.	(rr)
3	*Grammysia* (*Sphenomya*) *cuneata* Hall (?)	(rr)

4 *Grammysia* (Sphenomya) *arcuata* (Con.) Hall (rr)
5 *Spirifer mucronatus* (Con.) Bill. (?) (rr)
6 *Camarotoechia* sp. (rr)

These rocks are regarded as belonging in the Ithaca formation which consequently caps the hill and loose on the surface of its top are numerous angular fragments of rock, containing the Ithaca fauna, which evidently came from that region. On the highway crossing the hill, just over the divide on the eastern slope, is a ledge of sandstone and bluish shales (X^7) containing Ithaca fossils. This outcrop is about 50 feet higher than the arenaceous shales of X^5 in the field some distance to the west of the highway.

SECTION OF HILL SOUTH OF CHARLOTTEVILLE

XXVI X

596′		Top of hill
	9′	
587′		X^7 Sandstone and shales on road
	50′	
537′		X^5 Bluish fossiliferous shales. *Ithaca*
	122′	X^4 Covered
415′		
	5′	X^3 Bluish gray sandstone. *Sherburne* (?)
410′		
	402′	X^2 Covered
8′		
	8′	X^1 Sandstone. *Hamilton* (?)
0′		Charlotte river level

To the east of the hill described above, is the former hamlet of Morseville in the northern part of Jefferson township on the highway from Summit to Jefferson. On the hill east of Morseville is coarse grained, massive sandstone very similar in general appearance to the heavy sandstone seen at the base of the Oneonta sandstone along the valleys of the Susquehanna river and Schenevus creek. Farther south on the hill about two and one third miles west of north of Jefferson village and some 225 feet higher are massive deposits of this coarse grained sandstone (XXVII A[1]). As far as the color and lithologic appearance of this stone are concerned it would be difficult to distinguish it from typical exposures of the Oneonta sandstone in Otsego and Delaware counties. These ledges, however, are not considered to be stratigraphically as high as the base of the Oneonta sandstone in the Susquehanna valley; but it is thought that similar lithologic conditions appear at a lower horizon in rocks which are synchronous with the upper part of the Ithaca formation of Otsego co. It is believed the record of the observations across Schoharie co. will show that the conditions under which the Oneonta sandstone was deposited in Chenango, Otsego and Delaware counties occurred earlier and earlier as the formation is followed to the eastward till the Ithaca formation finally merged into the Oneonta. The change seems to have been about the same as the one described in Delaware county where the Chemung formation merges into the Catskill.

XXVII C[1]. About one and one fourth miles north of Morseville and two and one third miles southwest of Summit village in the southern part of Summit township is a conspicuous mound or circular hill. Its top is approximately 170 feet higher than the four corners at Summit and it is a conspicuous landmark when seen from the high land to the east of Summit as well as from other localities in Summit and Jefferson townships. The rocks are pretty well covered on the mound, but there are some exposures of shales and shaly sandstones; while the slope is quite well covered with loose pieces that evidently came out of the hill. *Spirifer mesastrialis* Hall with a few other species are found and

the rocks are evidently in the Ithaca formation. On the highway not far from the northern foot of the mound just described are bluish shales which break into very small pieces and alternate with thick bedded sandstones. No fossils were found and the rocks of this outcrop closely resemble those of the Sherburne formation. On the highway immediately to the north of Summit are bluish arenaceous shales—typical Hamilton—containing numerous fossils. The village is certainly situated on rocks of the Hamilton formation. A short distance to the northeast of it in a sort of basin cut out of Hamilton rocks is a small, very pretty, glacial lake, completely surrounded by fields and woods, which may very appropriately be called Summit lake. Its outlet forms one of the head branches of the Westkill. A view of the lake from the high hill to the north is given on one of the plates.

XXVII D. Two thirds of a mile to the north of Summit and Summit lake is a prominent somewhat circular hill which may be called Summit hill. From its summit a magnificent view in several directions may be had. To the south are the western Catskills of Delaware co.; to the southwest is the upper valley of the Charlotte river with its maze of hills and to the north and northeast is the valley of the Cobleskill lined by its steep hills. From this commanding position a clear idea of the irregular surface carved out of this plateau by the streams may be obtained. On the highway where the descent begins toward the Cobleskill at Richmondville are bluish arenaceous shales containing an abundant Hamilton fauna. From the highway a section was constructed along the quarry road up the southern side of the hill. The first 100 feet are covered and then for a few feet there are smooth, bluish shales without fossils. At an elevation of 115 feet rather coarse, bluish, arenaceous shales begin (D^2) resembling the Hamilton shales in all respects. There are 15 feet of these shales containing numerous specimens of Hamilton fossils. This zone is still in the Hamilton formation, although very near its summit. The complete list of species collected in D^2 is as follows:

Plate 7

View of Summit lake and the Catskills to the south

1	*Tropidoleptus carinatus* (Con.) Hall	(a)
2	*Spirifer mucronatus* (Con.) Bill.	(c)
3	*S. tullius* Hall	(c)
4	*Chonetes setigera* Hall	(rr)
5	*Orthis (Rhipidomella) vanuxemi* Hall	(rr)
6	*Camarotoechia congregata* (Con.) Hall & Clarke (?) Broken specimen.	(rr)
7	*Microdon (Cypricardella) gregarius* Hall	(a)
8	*Palaeoneilo muta* Hall	(rr)
9	*P. constricta* (Con.) Hall	(rr)
10	*Nucula corbuliformis* Hall	(rr)
11	*N. bellistriata* (Con.) Hall	(r)
12	*Nuculites oblongatus* Con.	(rr)
13	*Cimitaria recurva* (Con.) Hall	(rr)
14	*Grammysia bisulcata* (Con.) Hall	(rr)
15	*Goniophora hamiltonensis* (Hall) Miller (?)	(rr)
16	*Liopteria dekayi* Hall	(rr)
17	*Pterinopecten vertumnus* Hall	(rr)
18	*Dalmanites (Crypheus) boothi* (Green) Hall	(rr)
19	*Loxonema* sp. Only one whorl; too imperfect for specific identification.	(rr)

Above zone D^2 are much finer shales (D^3) which contain an occasional fossil and resemble considerably the Sherburne shales of Schoharie co. After 20 feet of these shales, however, there is an abundantly fossiliferous stratum of the coarser Hamilton-like shales (D^4) but a little more than a foot in thickness. Above and below D^4 are the fine, smooth shales containing only an occasional fossil. The fauna of D^4 is:

1	*Tropidoleptus carinatus* (Con.) Hall	(a)
2	*Vitulina pustulosa* Hall	(rr)
3	*Spirifer* cf. *granulosus* (Con.) H. & C. Internal impressions too imperfect for specific identification.	(r)
4	*Spirifer* sp.	(rr)
5	*Chonetes scitula* Hall	(rr)
6	Athyris spiriferoides (Eaton) Hall	

7 *Nuculites triqueter* Con. (rr)
8 *Nucula bellistriata* (Con.) Hall (r)
9 *Grammysia (Sphenomya) cuneata* Hall (c)
10 (?)*Prothyris* sp. (rr)
11 *Liopteria dekayi* Hall (rr)
12 *Pleurotomaria capillaria* Con. (rr)

This is the highest zone of Hamilton fossils found on the hill and is considered to mark the top of the formation above which are the shales and sandstones of the Sherburne formation.

Above the fossiliferous zone of D^4, 39 feet of the smooth, bluish, argillaceous shales are shown along the quarry road. These shales which weather to an olive tint and soon decompose into soil closely resemble in lithologic characters the Sherburne shales, to the base of which formation this zone is referred. The rocks are then covered for 35 feet when the base of the McDonald & Co's flagstone quarry (D^7) is reached near the top of the hill. There are 12 feet of rather coarse grained, blue sandstone shown in the quarry wall, the upper three feet of which have shaly partings. The stone is quarried for flagging though some of the layers are rather thick. The sandstone is covered by 38 feet of slightly olive and bluish argillaceous shales, (D^8) at the western end of the quarry and 31 feet at the eastern end, containing some thin layers of sandstone and all weather to a more or less brownish color. At one place on the floor of the quarry are fine ripple marks. Some time was spent in hunting for fossils over the large amount of debris from the quarry but nothing save a few rather poorly preserved specimens of *Lepidodendron* and fragments of plant stems was found. From the top of the quarry to the summit of the hill is some 20 feet more, all of which is covered. On the top of the hill is a monument of the New York state topographical survey that is 2428 feet A. T.

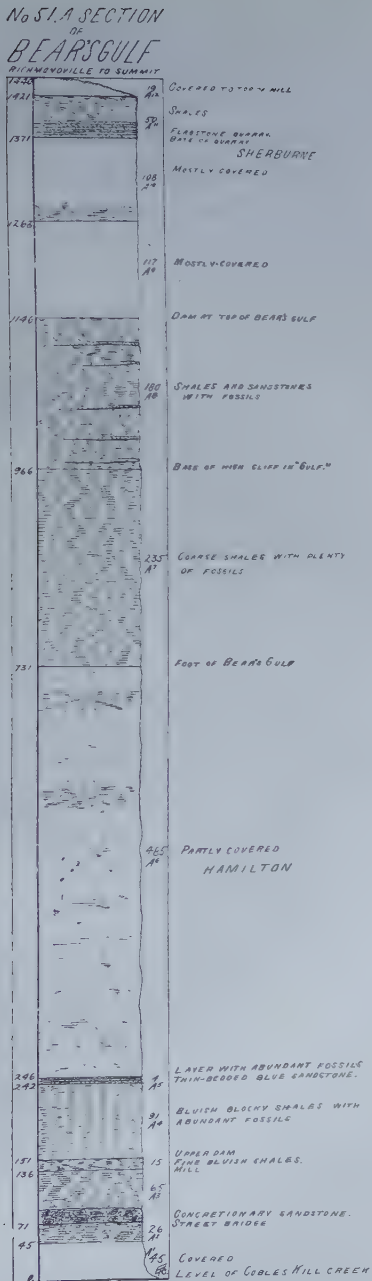
The highway was followed from the beginning of the descent to Richmondville and then to Warnerville which is near the top of the Onondaga limestone. Along the upper part of the hill are numerous outcrops of Hamilton shales and it is a good locality at which to study the upper part of that formation. The

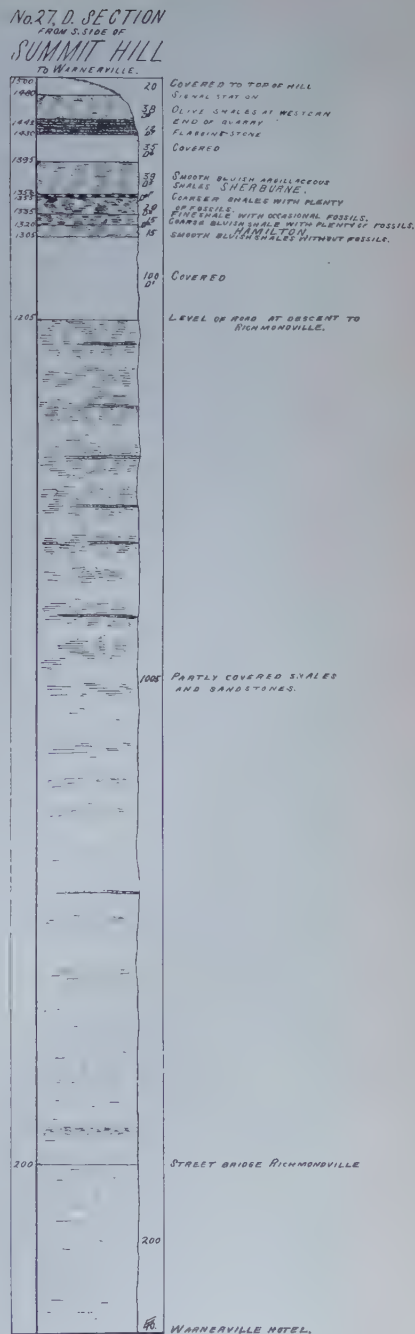
barometer gave a difference of 1155 feet from the fossiliferous band D^4 to the bridge above the Hamilton gorge in Richmondville. To this can be added the 26 feet of coarse, arenaceous shales shown in the creek in Richmondville which will give at least 1231 feet for the Hamilton formation in the northern slope of Summit hill. This, undoubtedly, is not the entire thickness of the formation since the shales in the Richmondville gorge are too coarse for the shales at the base of the Hamilton formation. From the base of the shales in the Richmondville gorge to the level of the Cobleskill is 45 feet, which is covered. The above section is a fairly accurate one, for the altitude of the Richmondville railroad station is 1174 feet A. T. and that of Summit hill 2428 feet, making a difference of 1254 feet between the station and the top of the hill; while the barometric section is 1276 feet which is only 22 feet too great. From the Richmondville gorge to Warnerville there is a fall of 200 feet which makes at least a thickness of 1355 feet for the Hamilton and Marcellus formations, without taking into consideration the dip which would increase the amount. The barometric section from the top of Summit hill to Warnerville is 1500 feet. This is not far from correct for the difference between the Cobleskill railroad station, near the same level as Warnerville, and the top of Summit hill is 1526 feet. The diagrammatic form of the above section is given in an accompanying figure.

LI A. The brook on which the Richmondville gorge, mentioned above, occurs rises in the northern part of Summit township and cuts a deep and narrow gorge on the northern slope of Summit hill known as Bear's gulf. There are numerous exposures along this stream to the gulf, and the section given has been constructed from the Cobleskill along this brook through Bear's gulf and to the top of Summit hill. The total thickness of the section is not as accurate as the one already described, for it makes the difference between the Richmondville railroad station and the top of the hill 1340 feet, which is 86 feet too great. The "gulf" is a narrow glen bounded by steep walls composed largely of Hamilton sandstones or coarse, arenaceous shales, a general idea of

which is here given; at the top is a cascade also shown on the plate, and at the top of that is a dam. The land on the western side of the gulf belongs to Mr William Harinahs and on the eastern side to Mr David Wilday. In part 2 of the magnificent work on the Lamellibranchiata of New York a number of species are credited to this locality and it is certainly a splendid place for collecting. There are numerous large blocks in the stream which have fallen from the cliffs along the sides of the gulf and they are filled with excellent fossils. On the section A^7 and A^8 are the exposures for Bear's gulf, the lower 235 feet of which are composed largely of coarse arenaceous shales containing an abundance of fossils, while at their top is the base of the high cliff. The cliff is composed of shales with rather thick, very fossiliferous sandstones and it is 180 feet from its base to the dam at the head of the gulf. Time did not permit a thorough search for fossils; but the following fauna was obtained from zones A^7 and A^8.

1	*Spirifer mucronatus* (Con.) Bill. The very mucronate forms.	(aa)
2	*S. granulosus* (Con.) H. & C.	(c)
3	*S. tullius* Hall	(c)
4	*Tropidoleptus carinatus* (Con.) Hall	(a)
5	*Liorhynchus multicosta* Hall	(a)
6	*Camarotoechia congregata* (Con.) H. & C.	(c)
7	*Productella* sp. Broken specimen.	(rr)
8	*Grammysia magna* Hall	(c)
9	*G. bisulcata* (Con.) Hall	(r)
10	*Glyptodesma erectum* (Con.) Hall	(rr)
11	*Pterinea flabella* (Con.) Hall	(rr)
12	*Microdon (Cypricardella) tenuistriatus* Hall	(rr)
13	*Nyassa arguta* Hall	(r)
14	*N. subalata* Hall	(rr)
15	*Palaeoneilo emarginata* (Con.) Hall	(rr)
16	*Liopteria dekayi* Hall (?)	(rr)
17	*L. bigsbyi* Hall	(rr)


No 51. A SECTION OF BEAR'S GULF
RICHMONDVILLE TO SUMMIT
1421
1371
1265
1146
966
731
246
242
151
136
71
45
Covered to top of hill
Shales
Flagstone quarry.
Base of quarry
SHERBURNE
Mostly covered
Mostly covered
Dam at top of Bear's Gulf
Shales and sandstones with fossils
Base of high cliff in "Gulf."
Coarse shales with plenty of fossils
Foot of Bear's Gulf
Partly covered
HAMILTON
Layer with abundant fossils
Thin-bedded blue sandstone.
Bluish blocky shales with abundant fossils
Upper dam
Fine bluish shales.
Mill
Concretionary sandstone.
Street bridge
Covered
Level of Cobles Kill Creek


No. 27, D. SECTION FROM S. SIDE OF SUMMIT HILL TO WARNERVILLE.
1500
1205
200
Covered to top of hill
Signal station
Olive shales at western end of quarry
Flagging stone
Covered
Smooth bluish argillaceous shales SHERBURNE.
Coarser shales with plenty of fossils.
Fine shale with occasional fossils.
Coarse bluish shale with plenty of fossils.
HAMILTON.
Smooth bluish shales without fossils.
Covered
Level of road at descent to Richmondville.
Partly covered shales and sandstones.
Street bridge Richmondville
Warnerville Hotel.

18 *Tentaculites bellulus* Hall (c)
19 *Camarotoechia prolifica* (Hall) H. & C. (r)
20 *C. sappho* (Hall) H. & C. (rr)
21 *Orthothetes chemungensis* (Con.) H. & C.
var. *arctostriatus* Hall (rr)
22 *Orthonota undulata* (Con.) (r)
23 *Orthoceras* sp. (rr)
24 *Chonetes coronata* (Con.) Hall (aa)
There are splendid specimens of the variety that was called *Strophomena syrtalis* Con.

The next 117 feet above the dam at the head of the gulf on the western side of Summit hill is mostly covered when a zone of fine bluish to greenish shales is reached (A^{10}) containing an occasional fossil as *Spirifer mucronatus* (Con.) Bill. This outcrop seems to be near that of zone XXVII D^3 of the section on the southern side of the hill. From the base of A^{10} to the floor of the quarry is 108 feet, the greater part of which is covered on the western slope of the hill. The remainder of the section is the same as that described in section XXVII D.

Emmons in describing the rocks near Summit referred the higher ones to the Chemung formation, stating that "At Summit in Schoharie county, in a deep gorge near the village, the Chemung group occupies the upper part and the higher slopes adjacent to it, and also the hills above the village. As yet, however, the fossils of the Chemung narrows are not common or numerous: and it seems to be established that the fossils of the Hamilton shales go up higher into the shales and flags, and occur nearer to the base of the Catskill division or Old Red sandstone, than at the west."[a]

In the above quotation it is not quite clear which gorge is meant, yet it is probable that its rocks are in the Hamilton instead of the Chemung formation. As already shown the hills to the north and northeast of Summit are capped by the Sherburne formation, or Portage as called by Emmons, and those to the south by the Ithaca.

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a Agriculture of New York, 1846, 1:192.

Jefferson

To the south of Summit is Jefferson, the southwestern township of Schoharie co., which is bounded on the south by Stamford and Harpersfield townships of Delaware co. and on the west by Harpersfield and a part of Summit. Across the central part extends an elevated ridge, from north to south, which culminates in Mt Jefferson. In the southern part of the township is the head of the Delaware river; near the center is the source of Middle brook, one of the largest branches of the upper Charlotte river; in the northwestern part are other branches of the Charlotte while on the east are the Westkill and the head waters of Mill creek and the Minekill all three tributaries of the Schoharie river. In the northern part of the township to the east of Morseville and northwest of Jefferson are ledges of coarse grained, greenish gray sandstone similar to the Oneonta, which have already been mentioned.

XXVII B². To the north of Jefferson village and Middle brook are exposures of thin sandstones and arenaceous shales, with some very calcareous layers which are composed largely of *Spirifer mesastrialis* Hall. These calcareous layers are called "fire stones" by the farmers and the loose pieces are picked up and used for arches. Some of the rocks were found in place at about the same elevation as the central part of the village; but it is approximately 190 feet lower than the coarse, greenish gray sandstone on the hill two and one third miles west of north of Jefferson (XXVII A¹). The most abundant fossil is *Spirifer mesastrialis* Hall which occurs in the calcareous layers, but some of the arenaceous shales contain specimens of a few species of Lamellibranchs. The complete list of specimens is as follows:

1	*Spirifer mesastrialis* Hall	(a)
2	*S. mucronatus* (Con.) Bill.	(r)
3	*Camarotoechia exima* (Hall) H. & C.	(c)
4	*Tropidoleptus carinatus* (Con.) Hall	(rr)
5	*Microdon (Cypricardella) gregarius* Hall	(a)

6	*M. (Cypricardella) complanatus* Hall	(rr)
7	*Modiomorpha mytiloides* (Con.) Hall (?)	(rr)
8	*Palaeoneilo emarginata* (Con.) Hall var.	(r)
9	*Nucula bellistriata* (Con.) Hall (?)	(r)
10	*N. corbuliformis* (Con.) Hall (?)	(rr)
11	*Goniophora* cf. *hamiltonensis* (Hall) Miller	(rr)
12	*Leptodesma rogersi* Hall (?)	(r)
13	*Actinopteria boydi* (Con.) Hall	(r)
14	*Tentaculites attenuatus* Hall (?)	(c)

These fossils are believed to occur between 350 and 400 feet above coarse, greenish gray sandstones which cap the hill between the Westkill and Mill creek to the west of North Blenheim in the Schoharie valley. The explanation is that the coarse sandstones with the facies of the Oneonta sandstone appear lower in the Schoharie valley than in the Charlotte and Susquehanna valleys. This replacement of the Ithaca formation by coarse, greenish gray and red sandstones in lithologic characters similar to those of the Oneonta sandstone is well shown along the Schoharie valley and to the eastward.

Mather in his report on the first geological district mentioned this locality north of Jefferson Academy, as Jefferson was then called. He wrote, "shells were seen in many places in the grits and gritty shales, between Summit and Jefferson Academy, especially on the high grounds and on the tops of the hills. They are particularly abundant about one mile north of Jefferson Academy."[a] He simply mentioned them under the Erie division of the rocks, which in his district included the Marcellus, Hamilton, Ithaca and Chemung groups without referring them to any formation. On the *Geological map of New York* published in 1844, all of Jefferson township, except the extreme northern portion, is colored as in the Catskill formation. This would make the heavy greenish sandstones near Morseville the base of the formation. The northern edge of Jefferson and the southern two thirds of Summit are colored as in the Portage and Chemung

a Geology of New York. 1844. Pt 1, p. 321.

formations, the northern part of Summit being included in the Hamilton.

Emmons discussed the rocks at Jefferson to some extent under the heading of the "Catskill group," though he apparently correlated them with the Chemung. He said, "Near the village, we discovered the same fossils as those of Gilboa, namely, the *Cypricardia*, *Tentaculites*, *Orthis*, etc. Besides the strata of crushed vegetables and the diagonal stratification already mentioned, Mr Hall has discovered a scale of the fish characteristic of the Old Red sandstone. In these discoveries we have the facts which have settled the character and age of the rocks in the southern part of Schoharie, Albany, and those of Greene and Delaware counties. They form one series of rocks, which may be traced south, southwest and west, through the southern tier of counties; and as a few fossils of the Chemung narrows have been found in Gilboa, we are able to connect the series with distant points west. The Chemung group, which had been supposed to be confined to the southwestern counties, has been proved, by the discovery of fossils, to occupy a place also at the base of the Catskill series. Of the *Dipleura dekayi* [*Homalonotus dekayi*], *Microdon bellistriata*, *Cypricardia angulata*, the latter is credited to Chemung narrows, while the two former are well known Hamilton fossils; these, with several others, occur 500 feet above strata which have hitherto been regarded as belonging exclusively to the Catskill series."[a]

XXVII B[1]. On the hill to the south of Jefferson and Middle brook is a prominent ledge of massive coarse gray to greenish sandstone, with reddish sandstone at the top, which is about 70 feet above the village hotel. This ledge in all its lithologic characters is like the Oneonta sandstone. Loose on the ground at this locality but apparently from this ledge are blocks containing *Spirifer mesastrialis* Hall, some of which contain large numbers of specimens; *Bellerophon* sp. and a scale "belonging in all probability to *Holoptychius americanus* Leidy" according to Dr Eastman were also found. The top of the ledge shows quite

[a] Agriculture of New York. 1846. 1:196.

a heavy dip to the southwest, being at the place measured 2° S, 46° W. This amount of dip seems to show that the coarse, greenish sandstones to the west of north of Jefferson and east of Morseville have been carried considerably below the surface at Jefferson; in fact if the dip be as great to the east of south for the entire distance then the sandstones to the north of Jefferson (XXVII A[1]) must be some 300 feet below the ledge (XXVII B[1]) to the south of the village. A view of this ledge was given in part 1 of this report on pl. 9. On the *Geologic map of New York* the base of the Oneonta sandstone is represented considerably farther south than the ledge of greenish and red sandstone to the south of Jefferson.

SCHOHARIE VALLEY SECTION

Crossing the eastern central part of Schoharie county from the south to the northeast is the Schoharie river,[a] which for the greater part of its course from Gilboa to Middleburg has cut a narrow and deep valley lined by steep and often precipitous hills. From Middleburg to the north the valley is generally broader although usually lined by steep hills with rocky slopes. It is a beautiful valley and the view from nearly all of the high hills to the east or west of the river is inspiring. In the writer's opinion the valley is one of the most beautiful in the state. The course of the Schoharie river has been well described by Prof. Guyot who said, "The main Schoharie creek originates at the foot of the Schoharie peaks [in the central chain of the Catskill mountains], near the head of the Plaaterkill clove, from which it is hardly separated by a slight swell in the swampy valley bottom." After describing its course through the Catskills he continues, "at the confluence of the Manorkill, it enters the mass of the northwestern plateaus, cutting from Gilboa 1033 feet, to Middleburg 640 feet, a deep and narrow valley, the bottom of which is from 1000 to 1300 feet below the general level of the

[a] On most of the maps this stream is called Schoharie *creek;* but on account of its length, over 76 miles, its volume of water, and the large area of country drained by it and its tributaries, the writer prefers to call it a *river*.

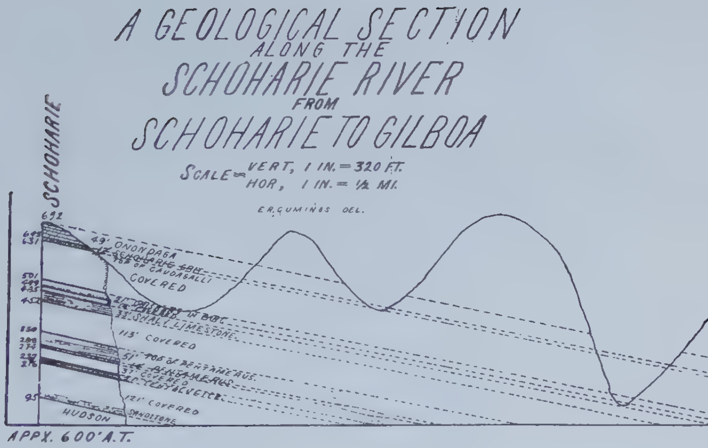
country it traverses, while the occasional flat bottoms in it at Blenheim, Breakabeen, Fultonham and Middleburg, rarely attain more than half a mile in width. Its course from Blenheim, through Middleburg, Schoharie and Central Bridge, where it receives the Cobleskill, is alternately to north-northeast and north. From this place instead of following the broad valley through which runs the Albany and Susquehanna railroad [now Susquehanna division of the Delaware and Hudson R. R.], it leaves it and cutting its way at right angles through the high hills which border the Mohawk, it finally enters that river near Fort Hunter, after a course of over 76 miles.

The contrast of the broad, open valleys between the mountain chains above described [the Catskills], and the narrow and deep cut of the Schoharie creek when passing through the plateau region is a feature to be noted.

This drainage which sends the waters of the Catskills all the way around to the Mohawk to come back by the Hudson, after a course of 175 miles, to within 10 miles of their starting point is certainly remarkable, and betokens a very peculiar physical structure. This is made more striking by the fact that on both sides of these highlands the waters of the valleys of the Catskill and Esopus creek flow, as we might have expected, from the western plateaus directly to the Hudson river. These three streams, which are so near each other, flow in opposite directions, and it seems as if this plateau of the Catskills had been lifted up on its eastern part to a higher level from which its waters were sent in the opposite direction."[a]

The importance of the Schoharie valley for geological investigation was early recognized by geologists and Mather wrote as follows concerning that portion of the valley about to be described more particularly, "The valley of Schoharie creek between Middleburg bridge and Gilboa, also offers fine opportunities for examining these strata [of his Erie division] and the valleys of the small streams that flow into the Schoharie kill

[a] Amer. jour. science, 3d ser., 1880, 19: 442-43.


A GEOLOGICAL SECTION
ALONG THE
SCHOHARIE RIVER
FROM
SCHOHARIE TO GILBOA
SCALE = VERT, 1 IN. = 320 FT.
HOR, 1 IN. = ½ MI.
SCHOHARIE
692
631
501
452
95
49' ONONDAGA
TOP OF CAUDAGALLI
COVERED
33' SHALY LIMESTONE
113' COVERED
51' TOP OF PENTAMERUS
37' COVERED
121' COVERED
HUDSON
SANDSTONE
APPX. 600' A.T.

offer still better opportunities."[a] While a section "from Esperance in Schoharie co. up the valley of Schoharie creek to Deep Clove" gives a good idea of the steep hills and narrow valleys, and fairly accurate limits for the lower formations.[b] The limits and correlations of the later formations not being clearly understood at that time are not represented with the same degree of accuracy.

Emmons referred frequently to the Schoharie valley region and in describing this route to the Catskills said, "The whole New York system is traversed by this route, and it leads up a beautiful valley, on the sides of which the strata are finely exposed in receding terraces or steep escarpments. Beautiful cascades and splendid scenery gratify the sight at every turn; while to the geologist the succession and stratigraphical arrangement is so clear and satisfactory, that all doubts are dispelled. The advantages of this route are decisive, in consequence of the fine field at Schoharie, where the succession is over a complete division of the Helderberg rocks; the Erie division is full and complete also, and may be observed first in the rounded hills about Schoharie village, dipping in the direction of the route of the creek; and the succeeding members slowly follow each other, till, finally, at Gilboa, the Catskill rocks are found at the base of the high ranges which have hedged in the creek for 25 miles."[c]

The rocks along the Schoharie river from Gilboa to Middleburg were also measured by Andrew and Clark Sherwood in 1873 under the direction of Prof. Hall and the section was published in 1878.[d]

On the accompanying "Geological section along the Schoharie river from Schoharie to Gilboa" the attempt is made to indicate something of the topography of the western side of the valley and the most conspicuous outcrops of rocks. There is no topographical map of that portion of New York and so on account of the absence of sufficient data it was only possible to indicate the most general features of the topography.

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a Geology of New York. 1843. Pt 1, p. 321.

b Ibid., plate 25, fig. 5.

c Agriculture of New York. 1846. 1 : 197.

d Proc. Amer. philosophical society. 17 : 347-49.

Middleburg

Middleburg is the next township in the Schoharie valley south of Schoharie, a famous geological region on account of the excellent outcrops of the Helderberg and Corniferous series on the high hills to the west and east of Schoharie village, known as West and East mountains. On the accompanying geologic section of the Schoharie river, a section of West mountain 690 feet in thickness is given showing the formations from the upper part of the Hudson river into the Onondaga limestone. The section will not be described more fully in this report since it is outside of the formations under consideration.

The central part of Middleburg township is crossed by the Schoharie river and the northern end of its gorge may be regarded as terminating near the southern border of the township. The geological formations underlying the greater part of the township are the Marcellus and Hamilton; the northern part of the township is cut down into the rocks of the Corniferous, Oriskany and Helderberg series, and to the south of Middleburg village near the top of Moheganter hill in the southern part of the township rocks of the Sherburne formation occur. The top of the Onondaga limestone shows in the Schoharie river about one half mile below Middleburg village where it makes a small fall;[a] and by the Middleburg and East Cobleskill highway crossing of the brook in the northwestern part of the township, some 190 feet above the river level. This gives a dip of over 105 feet a mile for the limestone.

To the east of Middleburg village is a prominent hill, the upper part of its western face being nearly perpendicular and the locality is known as "the cliffs." The rocks are sandstones and arenace shales containing Hamilton fossils which belong in the lower part of the formation. The view of this cliff given was taken from the eastern part of the village.

XXXVII B². On the eastern side of the river one mile south of Middleburg and about east of the prominent hill on the western side of the river known as Vroman's Nose, are ledges of sandstone and shales along the lower slope of the northern part of Moheganter hill. The base of these rocks is approximately 160 feet

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a Proc. Amer. philosophical society, 17:349.

above the Schoharie river at Middleburg and 200 feet of the section was studied, the upper ledge being a heavy sandstone stratum. The dip is heavy, being 2½° S 85° W in one place that was measured and on another ledge 2½° S 50° W. The lowest rocks are not very coarse but rather argillaceous shales in which fossils are rare. Then the shales change to a coarser texture, are more arenaceous, *Spirifer granulosus* (Con.) Hall is common and a few other species occur. Above is a bluish, blocky sandstone succeeded by arenaceous shales in which *Chonetes coronata* (Con.) Hall is common. And so the slope of the hill is terraced by ledges of sandstone and coarse shales which dip quite rapidly to the south. In the lower arenaceous shales and blocky sandstones fine specimens of *Spirophyton velum* (Van.) Hall are common. These rocks are all in the Hamilton formation and probably in its lower half.

1	*Spirifer acuminatus* (Con.) Hall	(rr)
2	*S. granulosus* (Con.) H. & C.	(a)
3	*S. mucronatus* (Con.) Bill.	(c)
4	*S. audaculus* (Con.) H. & C.	(rr)
5	*S. tullius* Hall	(rr)
6	*Chonetes coronata* (Con.) Hall	(c)
7	*C. deflecta* Hall	(rr)
8	*C. mucronata* Hall	(rr)
9	*Orthothetes chemungensis* (Con.) H. & C. var. *arctostriata* Hall	(rr)
10	*Athyris spiriferoides* (Eaton) Hall	(r)
11	*Stropheodonta perplana* (Con.) Hall	(rr)
12	*Camarotoechia congregata* (Con.) H. & C.	(rr)
13	*Liorhynchus multicosta* Hall	(rr)
14	*Paracyclas lirata* (Con.) Hall	(r)
15	*Goniophora rugosa* (Con.) Miller	(rr)
16	*Modiomorpha concentrica* (Con.) Hall	(rr)
17	*Glyptodesma erectum* (Con.) Hall	(rr)
18	*Spirophyton velum* (Van.) Hall	(r)

XXXVII D. A section was examined in the southern part of Middleburg and across into the northwestern part of Broome township, from two and one half to three miles south of the village of Middleburg and on the eastern side of Moheganter hill. The first rocks studied are those of a small stone quarry (D^2) in the

southern part of the township about two and one half miles south of the village. According to the barometer the quarry is some 830 feet higher than the Schoharie river at Middleburg. At the base of it are six feet of blue sandstone covered by 15 feet of shales with some thin layers of sandstone. In the shales are plenty of Hamilton fossils; specially in the thin layers and in some that have a rather concretionary structure. The rocks of this quarry are in the Hamilton formation and the following fossils were collected:

1 *Spirifer granulosus* (Con.) H. & C. (?) (c)

The specimens are poorly preserved. Some show impressions of the pustules and one shows fine striae; but in form and general appearance they are like the above species.

2 *Camarotoechia congregata* (Con.) H. & C. (r)
3 *Spirifer mucronatus* (Con.) Bill. (c)
4 *Chonetes coronata* (Con.) Hall (r)
5 *Athyris spiriferoides* (Eaton) Hall (rr)
6 *Palaeoneilo maxima* (Con.) Hall (r)
7 *P. emarginata* (Con.) Hall (rr)
8 *P. tenuistriata* Hall (rr)
9 *Nuculites triqueter* Con. (r)
10 *Nucula bellistriata* (Con.) Hall (c)
11 *N. randalli* Hall (rr)
12 *Paracyclas lirata* (Con.) Hall (r)
13 *Modiomorpha subalata* (Con.) Hall (?) (rr)

Small specimens.

14 *M. mytiloides* (Con.) Hall (rr)
15 *Goniophora hamiltonensis* (Hall) Miller (rr)
16 *G. truncata* Hall (rr)
17 *Cimitaria elongata* (Con.) Hall (r)
18 *Tellinopsis submarginata* (Con.) Hall (?) (rr)
19 *Sphenotus solenoides* Hall (?) (rr)

There are no vascular lines on the posterior part of the shell.

20 *Microdon (Cypricardella) tenuistriatus* Hall (c)
21 *Schizodus appressus* (Con.) Hall (r)
22 *Actinopteria boydi* (Con.) Hall (c)
23 *Pterinea flabella* (Con.) Hall (rr)
24 *Limoptera macroptera* (Con.) Hall (rr)

25 *Pterinopecten undosus* Hall (?) (rr)
26 *Ariculopecten princeps* (Con.) Hall (?) (rr)
27 *Orthoceras crotalum* Hall (rr)
28 *Orbiculoidea (Lindstroemella) aspidium* H. & C. (rr)

Approximately 340 feet above the stone quarry and south of the highway up the hill in northwestern Broome, just over the township line, is a small excavation showing blue sandstone (D^4) which splits into rather thin layers. No fossils were found in the bed rock; although there are plenty in loose pieces of stone on the surface which, however, probably came with the drift. On the highway just after it turns south in the northwestern corner of Broome and 145 feet above D^4 are green shales and thin sandstones (D^6) which are in the Sherburne formation. On the highway 30 feet higher near the turn to Franklinton are red and green mottled shales and sandstones (D^8). Another prominent terrace of grayish, slightly reddish and greenish shaly sandstone (D^{10}) appears 65 feet higher. Below this terrace along the highway are shales which are mainly red. At the top of the ridge is grayish and greenish gray, coarse grained, thin bedded sandstone (D^{12}). In the field plenty of loose red sandstone is found. The summit of the hill in the eastern part of Fulton township is only about 35 feet higher and this summit according to the barometric section is 1500 feet above the Schoharie river at Middleburg. On the side of the hill are loose specimens of rock containing Hamilton species, the following having been collected:

1 *Spirifer mucronatus* (Con.) Bill. (c)
2 *Tropidoleptus carinatus* (Con.) Hall (r)
3 *Camarotoechia sappho* Hall (?) (rr)
Imperfect specimens.
4 *Pleurotomaria sulcomarginata* Con. (?) (r)
Internal impressions poorly preserved.

The rocks from D^8 to the top of Moheganter hill have in general the lithologic characters of the Oneonta formation to which they would ordinarily be referred. The reds and greenish gray rocks on this hill, however, appear stratigraphically much lower than the base of the Oneonta sandstone in the Susquehanna valley or even in the western part of Schoharie co., so that they have nearly, if not completely, replaced the rocks of the Ithaca

formation. This fact will be shown still more clearly by the section of the western side of Moheganter hill (XXXVII C) in the eastern part of Fulton township. This section southeast of Middleburg and up the eastern side of Moheganter hill is shown in the following diagram.

SECTION UP THE LITTLE SCHOHARIE CREEK INTO THE NORTHWESTERN CORNER OF BROOME TOWNSHIP

XXXVII D

1500′		Top of Moheganter hill at corners	
	35′		
1465′		D^{12} Grayish and greenish gray sandstone	
	35′		
1430′		D^{10} Grayish and greenish sandstone	
			Oneonta
	65′		
1365′		D^{8} Red and green mottled sandstone and shale	
	30′		
1335′		D^{6} Green shales	
	145′		*Sherburne*
1190′		D^{4} Thin blue sandstone	
	340′	D^{3} Covered	
850′			
	20′	D^{2} Quarry of blue sandstone and shale	
830′			*Hamilton*
	515′	D^{1} Mainly covered	
315′		Bridge across creek 2½ miles S. E. of Middleburg	
	315′	D^{1} Covered	
0′		Schoharie river at Middleburg	

Fulton

The next township to the south in the Schoharie valley is Fulton which lies to the southwest of Middleburg and east of Summit. Its eastern-central part is crossed by the Schoharie river bordered by steep and high hills that south of Fultonham on the western side and north of Breakabeen on the eastern side have nearly perpendicular cliffs several hundred feet in hight. The western line of hills is broken by the creek at Fultonham and again by Panther or Kenhuragara creek between Fultonham and Breakabeen, and the eastern line by Keyser's creek and a brook at Breakabeen.

XXXVII C. In the southern part of Middleburg to the east of the Schoharie river is Moheganter hill which extends into Fulton township. Three miles southwest of Middleburg village, near the schoolhouse of district no. 11, the face of the hill is cut by a small brook and at this locality a road leaves the river road and climbs to the top of the high hill. A section was measured from the level of the Schoharie river along the brook and highway to the top of the hill at this locality which from a geological standpoint is a very interesting study. The section is near the Middleburg-Fulton township line being partly in each township, and its base is about opposite Watsonville on the western side of the river. The lower 200 feet are covered, largely by sand; but then a ledge of coarse, arenaceous shales and thin sandstones (C^2) is reached. This ledge is in the woods where it forms a cliff 30 feet high. The dip is between $1\frac{1}{2}°$ and $2°$ S, 70° W. The rocks contain abundant Hamilton fossils and belong near the middle part of the formation. The following fauna was obtained:

1 *Spirifer mucronatus* (Con.) Bill. (c)

2 *S. granulosus* (Con.) H. & C. (rr)

3 *Athyris spiriferoides* (Eaton) Hall (c)

4 *Camarotoechia congregata* (Con.) H. & C. (r)

5 *Microdon (Cypricardella) tenuistriatus* Hall (?) (rr)
Imperfect and worn.

6 *Chonetes mucronata* Hall (c)
Specimens larger than the figures of this species.

7 *Chonetes deflecta* Hall (c)
8 *Palaeoneilo tenuistriata* Hall (rr)
9 *Macrodon hamiltoniae* Hall (rr)
10 *Grammysia bisulcata* (Con.) Hall (r)
11 *Tellinopsis subemarginata* (Con.) Hall (rr)
12 *Pterinea flabella* (Con.) Hall (rr)
13 *Cyrtolites (Cyrtonella) pileolus* Hall (rr)

From the top of this ledge for 135 feet to the schoolhouse at the road corners there are occasional outcrops of arenaceous shales, and then for 305 feet along the road and brook the rocks are mostly covered. By the side of the highway just above the house of Mr George P. Bouck and about one mile above the river road is an outcrop of from eight to 10 feet of Hamilton shales (C^4). Those at the base are rather fine but the upper ones are coarser. The shales are mainly argillaceous and contain numerous Hamilton fossils. The list is:

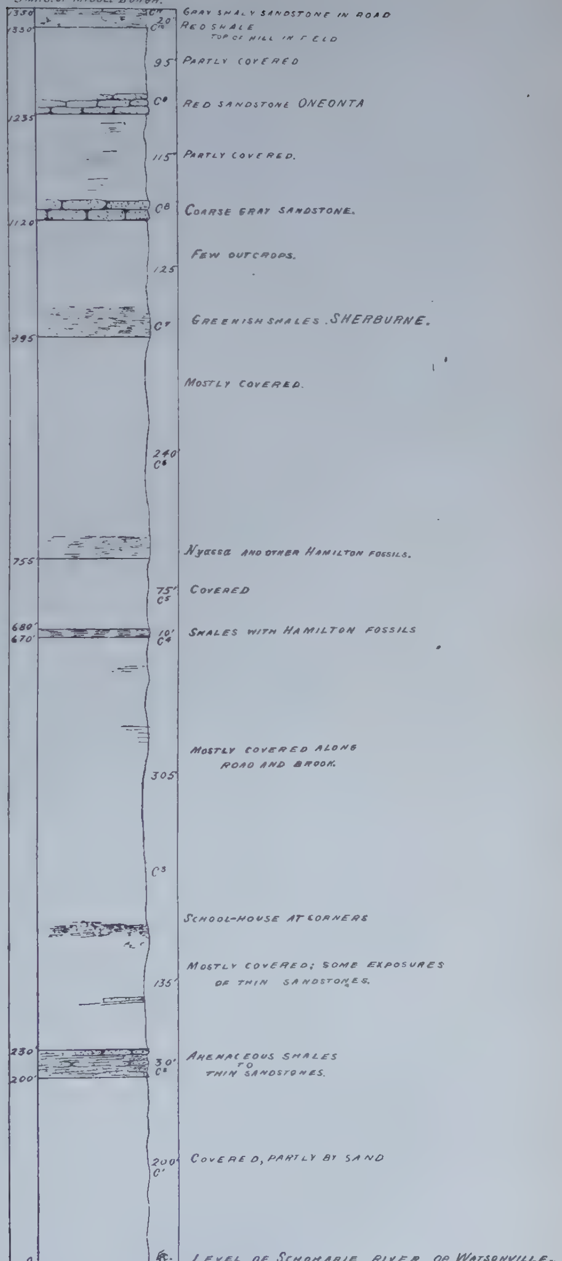
1 *Spirifer mucronatus* (Con.) Bill. (r)
2 *Cryptonella (Eunella) lincklaeni* Hall (c)
3 *Athyris spiriferoides* (Eaton) Hall (rr)
4 *Productella dumosa* Hall (?) (rr)
5 *Camarotoechia prolifica* (Hall) H. & C. (rr)
6 *Goniophora hamiltonensis* (Hall) Miller (rr)
7 *Nuculites oblongatus* Con. (rr)
8 *Palaeoneilo constricta* (Con.) Hall (rr)
9 *Cimitaria elongata* (Con.) Hall (?) (rr)
Imperfect.
10 *Actinopteria boydi* (Con.) Hall (c)

75 feet higher and 755 feet above the Schoharie river are very thin, bluish, argillaceous shales (C^6). In a layer of somewhat coarser shales is an abundance of specimens of *Nyassa arguta* Hall; while a little higher are some thin layers of concretionary sandstone. These shales are referred to the Hamilton formation and the following fossils were collected:

1 *Cryptonella (Eunella) lincklaeni* Hall (c)
2 *Athyris spiriferoides* (Eaton) Hall (a)
Abundant in a layer of thin, shaly rock.

No. 37, C. SECTION
OF
MOHEGANTER HILL

3 MI. S. OF MIDDLEBURGH.



3 *Camarotoechia prolifica* (Hall) H. & C. (a)
Abundant in same layer as above.
4 *Spirifer mucronatus* (Con.) Bill. (rr)
5 *Nyassa arguta* Hall (aa)
6 *Paracyclas lirata* (Con.) Hall (rr)
7 *Goniophora hamiltonensis* (Hall) Miller (rr)
8 *Pterinea flabella* (Con.) Hall (rr)
9 *Liopteria bigsbyi* Hall (rr)
10 *Cyrtolites* (*Cyrtonella*) *mitella* Hall (rr)

By the roadside 240 feet higher and 995 feet above the Schoharie river are thin, greenish, argillaceous shales and some that are arenaceous (C^7). These shales are referred to the Sherburne formation which they closely resemble in lithologic appearance. For the succeeding 125 feet the rocks are well covered though there is an occasional outcrop of the greenish shales; then a coarse grained, greenish gray sandstone (C^8) with crossbedding is reached. Then the slope for 115 feet is partly covered with an occasional outcrop of the grayish to greenish sandstone. 55 feet above the lowest ledge of these sandstones are thinner gray sandstones, and in some rather shaly layers a few imperfectly preserved fossils were found—a remnant of the Ithaca fauna—which at that locality, by the changed conditions of deposition, had narrowly escaped complete extermination. At 1235 feet above the river level is a thick, unusually hard ledge of reddish, indurated sandstone. Above, the slope though partly covered shows frequent outcrops of red and greenish shales. 95 feet above the top of the reddish sandstone at the top of the brow of the hill are soft, argillaceous red shales. On the highway about 20 feet higher are grayish, shaly sandstones (C^{11}), and 50 feet higher is another outcrop of coarse grained, greenish gray sandstone. The bedding is somewhat irregular but not thick and there is a layer of breccia. The only fossils found in place in these upper deposits were fragments of plant stems. By the side of the road, in loose pieces above the red shales, specimens of *Tropidoleptus carinatus* (Con.) Hall, *Spirifer mucronatus* (Con.) Bill. and *Camarotoechia prolifica* (Hall) H. & C. were found. It is

not probable, however, that these fragments came from this part of the hill, but they were undoubtedly left by the ice sheet near the summit of Moheganter hill. On a stone wall in this vicinity large flat blocks of sandstone were seen which contained the following species, the first one occurring in large numbers:

1	*Chonetes coronata* (Con.) Hall	(aa)
2	*Tropidoleptus carinatus* (Con.) Hall	(a)
3	*Camarotoechia prolifica* Hall	(c)
4	*Spirifer mucronatus* (Con.) Bill.	(r)
5	*Athyris spiriferoides* (Eaton) Hall	(r)

From this last outcrop to the top of the hill at the corners, mentioned in section XXXVII D, is 40 feet which makes it 1440 feet above the level of the Schoharie river at its base. The barometric section from Middleburg village up the Little Schoharie and the eastern slope of Moheganter hill (XXXVII D) to the road corners made it 1500 feet; so in the elevations there is probably not a very serious error in the case of either section. This section is here represented diagrammatically. On account of the covered slope it is not possible to indicate closely the line of division between the Hamilton and Sherburne formations. There are at least 755 feet of rocks above the level of the Schoharie river belonging in the Hamilton and probably part of the succeeding covered 240 feet belongs in the same formation. The 240 feet above the covered zone to the base of the heavy red sandstone is referred to the Sherburne and Ithaca formations, the thickness of which probably should be increased by a portion of the underlying covered zone. The rocks from the base of the red sandstone (C^9) to the summit of the hill are referred to the Oneonta formation. It is clearly recognized that to the west of the Schoharie river, rocks at this horizon are not red and are not called Oneonta but are referred to the Ithaca formation. A little farther east, however, along the Schoharie-Albany co. line and to the eastward, the red rocks near this horizon and still lower have been mapped and correlated with the Oneonta formation. In that region it is impossible to follow any line of division between the Ithaca and Oneonta formations, for the

Oneonta has replaced the Ithaca in the same manner as the Catskill replaces the Chemung in Delaware co., and the author considers it advisable to follow the precedent of the state survey and so apply the term Oneonta formation to these rocks although it is quite true that they are synchronous with rocks which in the Susquehanna valley are referred to the Oneonta, Ithaca and upper Sherburne formations. The above statement explains why the Oneonta formation is represented on the *Geologic map of New York* so much farther north on the eastern than on the western side of the Schoharie river; and correctly so, provided the lower mass of coarse greenish gray and red sandstones with red shale, which can not be separated from the Oneonta formation in its typical region, be referred to that formation. On the eastern side of the Schoharie river the author has referred the rocks to the Oneonta formation beginning with the lowest red sandstones or shales of any considerable thickness. The sandstones below are frequently coarse and similar to those in the Oneonta, but the stratigraphic position and the occurrence of a few fossils in the alternating shales have decided the author to correlate them in general with the Sherburne formation. On the *Geologic map of New York* the top of Moheganter hill and the high land between Breakabeen and Franklinton are represented as in the Hamilton formation (the upper part of which included the Ithaca and Sherburne formations) but it should be represented in the Oneonta for the rocks of corresponding stratigraphic position on the high ground to the northeast of Franklinton and to the south and east of Huntersland are so represented. On the accompanying geologic map it will be noticed that the base of the Oneonta formation to the east of the Schoharie river is represented nearer the western brow of the steep hills than on the *Geologic map of New York* and that it runs north into the northwestern corner of Broome township and then southeasterly along the side of the steep hill to the southwest of the upper part of the Catskill creek, till it crosses that creek below Livingstonville near the county line. To the northeast of the Catskill creek across the northeastern part of Broome town-

ship into Albany co. the lines on the two maps agree quite closely. On the *Geologic map of New York* published in 1844 all the high country in Broome and Conesville townships in the eastern part of Schoharie co. is mapped as belonging to the Portage and Chemung formations, which were not separated on the map.

Along the highway from the corners at the schoolhouse of district no. 11 in Middleburg to Houston Corners east of Breakabeen there are occasional ledges of shales and sandstones which are in the upper part of the Hamilton formation. Opposite Blenheim hill, the name applied to the high hill on the western side of the river between Fultonham and Panther creek, on the roadside are fairly gritty blue, sparingly fossiliferous shales (XXIX B[1]) from which the following species were collected:

1 *Tropidoleptus carinatus* (Con.) Hall (c)

2 *Camarotoechia congregata* (Con.) H. & C. (c)

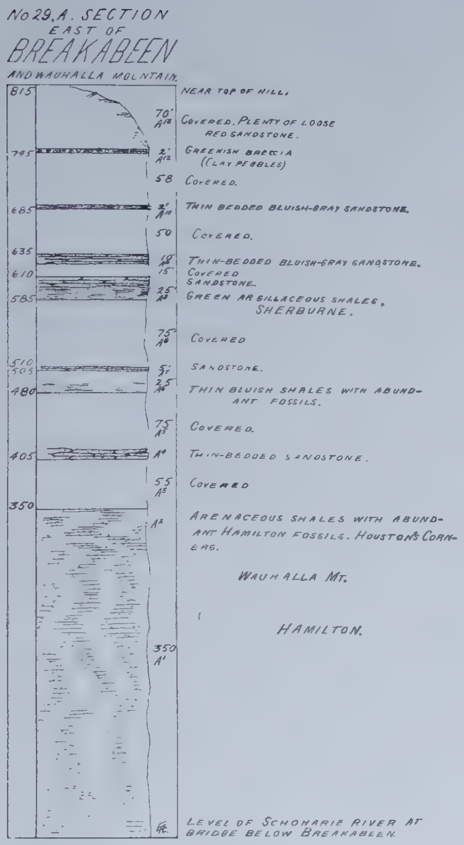
3 *Liopteria* sp. (rr)

Badly broken specimen.

4 *Modiomorpha subalata* (Con.) Hall (?) (rr)

Imperfectly preserved specimen.

XXIX A'. On the eastern side of the Schoharie below Breakabeen there is a perpendicular cliff of shales alternating with sandstones rising from the river estimated as between 60 and 70 feet high, then a line of trees, then another perpendicular cliff and at the top a third one. A hill crowns the summit and the entire exposure is known as Wauhalla mountain. A view of this cliff from near the river road on the western side is here shown. A section was constructed from the river level at the highway bridge below Breakabeen through Houston Corners to a point near the top of the hill to the north of east of the Corners and the diagrammatic form is here given. On the western bank of the river at the highway bridge below Breakabeen are blue, somewhat irregular shales alternating with blue sandstone layers varying in thickness from two inches to a foot. The shales at the northern end of the bridge contain large numbers of *Paracyclas lirata* (Con.) Hall associated with other Hamilton


No 29, A. SECTION
EAST OF
BREAKABEEN
AND WAUHALLA MOUNTAIN.
815
NEAR TOP OF HILL.
70'
COVERED. PLENTY OF LOOSE RED SANDSTONE.
745
2'
GREENISH BRECCIA (CLAY PEBBLES)
58
COVERED.
685
THIN BEDDED BLUISH-GRAY SANDSTONE.
50
COVERED.
635
10'
THIN-BEDDED BLUISH-GRAY SANDSTONE.
610
15'
COVERED
SANDSTONE.
585
25'
GREEN ARGILLACEOUS SHALES.
SHERBURNE.
75'
COVERED
510
505
5'
SANDSTONE.
480
25
THIN BLUISH SHALES WITH ABUNDANT FOSSILS.
75
COVERED.
405
THIN-BEDDED SANDSTONE.
55
COVERED
350
ARENACEOUS SHALES WITH ABUNDANT HAMILTON FOSSILS. HOUSTON'S CORNERS.
WAUHALLA MT.
HAMILTON.
350
LEVEL OF SCHOHARIE RIVER AT BRIDGE BELOW BREAKABEEN.

fossils; while the sandstone layers contain some different species. A layer of ferruginous concretions is noticeable. The dip on the western bank is from 1° to 1½° S 64° W and on the eastern bank it is more than 1° in amount, west of south (the exact direction and amount were not determined on account of the distance at which the observation was made).

The rocks next studied (A^2) are in a small brook at Houston Corners, three quarters of a mile east of Breakabeen and 350 feet above the river. The outcrop consists of coarse, arenaceous shales to shaly sandstones, the latter containing numerous specimens of the large Hamilton Lamellibranchs. These rocks are clearly of the Hamilton formation and the following species were collected:

1	*Camarotoechia prolifica* Hall	(r)
2	*Chonetes coronata* (Con.) Hall	(rr)
3	*Spirifer mucronatus* (Con.) Bill (?)	(rr)
4	*Tropidoleptus carinatus* (Con.) Hall	(rr)
5	*Liopteria greeni* Hall	(rr)
6	*Glyptodesma erectum* (Con.) Hall (?)	(rr)
7	*Goniophora hamiltonensis* (Hall) Miller	(rr)
8	*Grammysia alveata* (Con.) Hall	(c)
9	*Phacops rana* (Green) Hall	(rr)
10	*Microdon (Cypricardella) bellistriatus* Con.	(rr)
11	Crinoid stems	

On the slope of the hill to the north of east of the ledges in the brook at the Corners, the rocks are covered for 55 feet, when a zone of thin bedded sandstones (A^4) is reached. This outcrop of somewhat crossbedded sandstones about 10 feet thick is immediately above the road leading northeast from Houston Corners toward the top of Moheganter hill. The dip varies; but perhaps will average 1½° S 20° W. The ledge was not sufficiently broken to enable one to easily determine whether it contained fossils or not. About 65 feet above it are thin bluish shales (A^6) containing abundant fossils. These shales hardly form a ledge but from the way in which they lie on the surface

there seems to be no doubt that they belong at that horizon, and are apparently in the Hamilton formation. The following species were collected:

1	*Camarotoechia prolifica* (Hall) H. & C.	(a)
2	*Ambocoelia umbonata* (Con.) Hall	(rr)
3	*Strophalosia truncata* (Hall) Beecher	(rr)
4	*Pterinea flabella* (Con.) Hall	(c)
5	*Nyassa arguta* Hall	(c)
6	*Nuculites oblongatus* Con.	(rr)
7	*Palaeoneilo constricta* (Con.) Hall	(rr)
8	*Nucula bellistriata* (Con.) Hall	(rr)
9	*Tellinopsis subemarginata* (Con.) Hall	(rr)
10	*Tentaculites bellulus* Hall	(r)

25 feet above the base of these shales is a ledge of thin bedded, grayish sandstone (A^7) from four to five feet in thickness in which no fossils were found. Then there is a covered slope of 75 feet when, at an altitude of 585 feet (barometric) above the river, the base of decidedly green argillaceous shales (A^9) is reached. These are capped by thin bedded, grayish sandstones and together they have a thickness of 25 feet. Careful search was made in the green shales for fossils, but without success and the rocks have the lithologic appearance of the Sherburne to which formation they are referred. After 15 feet of covered slope there is a ledge of thin bedded, unfossiliferous bluish gray sandstone (A^{10}) about 10 feet in thickness. For the remaining upper part of the hill the rocks are mostly covered, two feet of a bluish gray thin bedded sandstone outcropping at 685 feet above the river, and a two foot stratum of greenish breccia with clay pebbles at 745 feet. The hill was examined 70 feet higher to 815 feet, which is near its top, but no further ledges were noticed. On this upper slope of the hill, however, are plenty of loose blocks of red sandstone probably in place near that horizon or perhaps that once capped the hill and through erosion have dropped down its side. In the above section the Hamilton extends fully 480 feet above the level of the Schoharie river, and a little more

than 100 feet above it green shales and sandstones are reached which are apparently in the Sherburne formation. On the Moheganter hill section 240 feet higher than the bottom of similar greenish shales, also referred to the Sherburne formation is the base of the zone of red sandstone and red and green shale fully 100 feet in thickness. The same thickness above the green shales on the Houston Corners hill will carry the section slightly higher than the hill was studied. The large amount of loose angular blocks of red sandstone, however, seen on the covered slope of the upper 70 feet of the section indicates the presence of the red rocks on that hill somewhere near that horizon. The Sherwood brothers gave a measured section of the Wauhalla mountain in their Schoharie river section, the base being the "gray shaly sandstone" of their no. 18, while the top is in no. 31 a "gray sandstone."[a] Their section makes the top of Wauhalla mountain between 533 and 605 feet above the level of the Schoharie river and near the same horizon as the greenish shales on the Houston hill which we have referred to the Sherburne formation.

XXIX X. The highway was followed up Keyser's creek from Houston Corners nearly to the southeastern corner of Fulton township; but without satisfactory results on account of the mantle of drift which conceals most of the rocks. On the creek banks some 110 feet above zone A^2 at Houston Corners are bluish shales and sandstones (X^1) which are probably in the Hamilton formation although no fossils were seen. From the creek to the highway, approximately 185 feet, the rocks are completely concealed; but on the hill northeast of the road there are two ledges of coarse greenish gray sandstone, one at 420 feet above the creek and the other near the top of the hill at 780 feet above the creek. Loose on the hillside between the two outcrops of the greenish sandstone are numerous large blocks of the red sandstone which evidently occurs somewhere in that part of the hill. The stratigraphic position of these red sandstone blocks agrees in a general way with its supposed horizon near the top

[a] Proc. Amer. philosophical soc. 1878, 17 : 348.

of the hill east of Houston Corners. This section is shown in the following diagram.

SECTION OF HILL NORTHEAST OF KEYSER'S CREEK

XXIX X

780′		Coarse greenish sandstone near top of hill	X^3
	360′	Large numbers of loose blocks of red sandstone	
420′		Greenish sandstone	
	420′	185[1] Highway. X^2 covered	
		X^1 Blue shales and sandstones	
0′		Keyser's creek, 110 feet above Houston Corners	

XXIX M. Above Keyser's creek, a smaller stream than it enters the Schoharie river at Breakabeen. A section was examined along this stream from east of south of Breakabeen to the high land near its source in the northern part of Gilboa township. 200 feet above the Schoharie river are bluish shales (M^2) clearly enough in the Hamilton formation, containing plenty of Hamilton fossils and the following species were collected:

1	*Camarotoechia prolifica* Hall	(c)
2	*Spirifer mucronatus* (Con.) Bill.	(rr)
3	*Nucula bellistriata* (Con.) Hall	(rr)
4	*Grammysia arcuata* (Con.) Hall	(rr)
5	*Homalonotus dekayi* (Green) Emm.	(rr)
6	*Tentaculites bellulus* Hall (?)	(rr)

Then there is a long slope deeply covered by drift and the next outcrop, consisting of coarse grained grayish sandstones (M^4) which split into thin layers is 540 feet above M^2. The only fossils seen were fragments of plant stems and the outcrop is well toward the head of the small valley. 100 feet higher, how-

ever, or 840 feet above the Schoharie river and probably across the township line in Gilboa, perhaps three miles from Breakabeen, are fossiliferous rocks (M^6). At the base of the outcrop is just a little greenish, argillaceous shale, while above are bluish gray, thin sandstones and shales containing some fossils. Specimens of *Tropidoleptus carinatus* (Con.) Hall are common, and *Spirifer mucronatus* (Con.) Bill. occurs less frequently. Above this fossiliferous zone there is another long drift covered slope, but 410 feet higher, near the turn toward North Blenheim, red argillaceous shales outcrop on the highway. This section may be tabulated as follows:

SECTION OF HILL EAST OF SOUTH OF BREAKABEEN INTO NORTHERN GILBOA

XXIX M

1250′		M^8 Red shale near turn to N. Blenheim	*Oneonta*
	410′	M^7 Covered	
840′		M^6 Bluish-gray shaly sandstone with fossils	
	100′	M^5 Covered	
740′		M^4 Coarse grained grayish sandstone	*Sherburne*
	540′	M^3 Covered	
200′		M^2 Bluish fossiliferous shales.	*Hamilton*
	200′	M^1 Covered	
0′		Schoharie river at Breakabeen	

As so much of this hill is covered it is difficult to correlate the different zones with those of the sections at Houston Corners and Moheganter hill. There was no evidence of the red sandstone and shale noted in the upper part of Moheganter hill, still it may be present and concealed by the drift. If not, then the red shale does not appear at as low a geologic horizon in this section as in Moheganter hill and there is a greater thickness of the Ithaca formation.

XXXVII A. Crossing to the western side of the Schoharie river and beginning on the northern border of Fulton township the first rocks examined are those on the bank of Mill creek which forms the boundary between Middleburg and Fulton townships. To the south of the lower course of the creek is a steep hill known as Vroman's Nose and at its northern end on Mill creek there is a bank of black, argillaceous shales 15 feet in thickness (A^2). This outcrop is about 75 or 80 feet above the Schoharie river and perhaps one mile south of west of Middleburg. The shales which are very fissile and contain some quite large, rounded concretions are like the typical Marcellus shales in both lithologic appearance and fauna and belong in that formation. There are but few fossils but specimens of the following species were collected:

1 *Chonetes mucronata* Hall (?) (rr)

2 *Styliola fissurella* Hall (a)

In certain layers.

3 *Orthoceras subulatum* Hall (?) (rr)

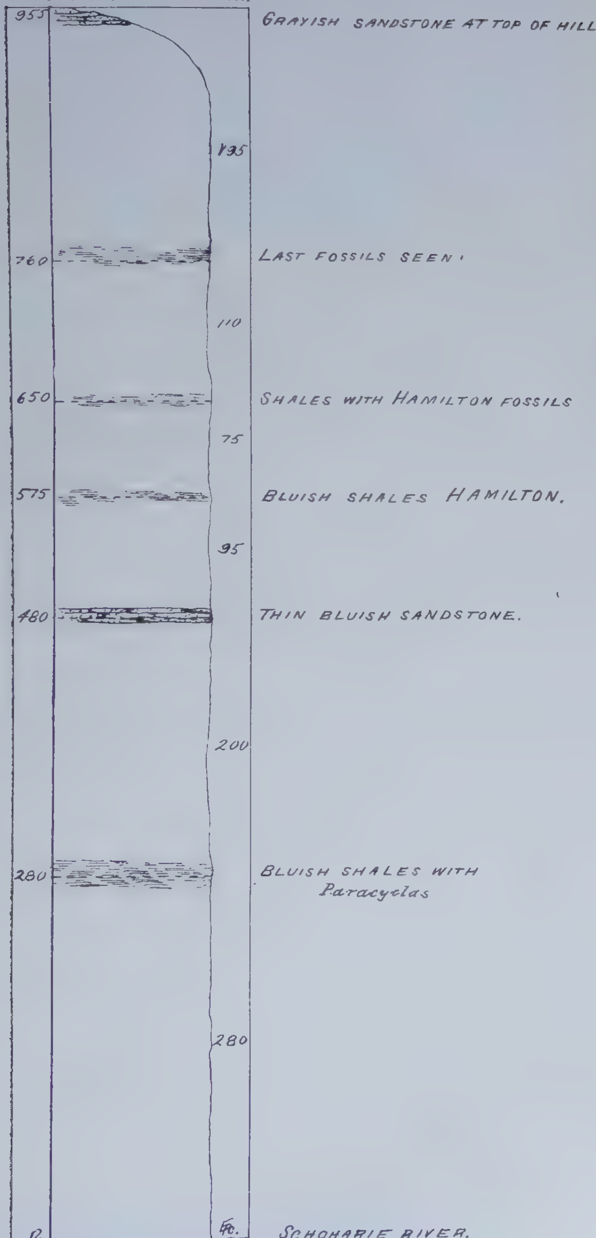
Fragment.

4 Crinoid segment (rr)

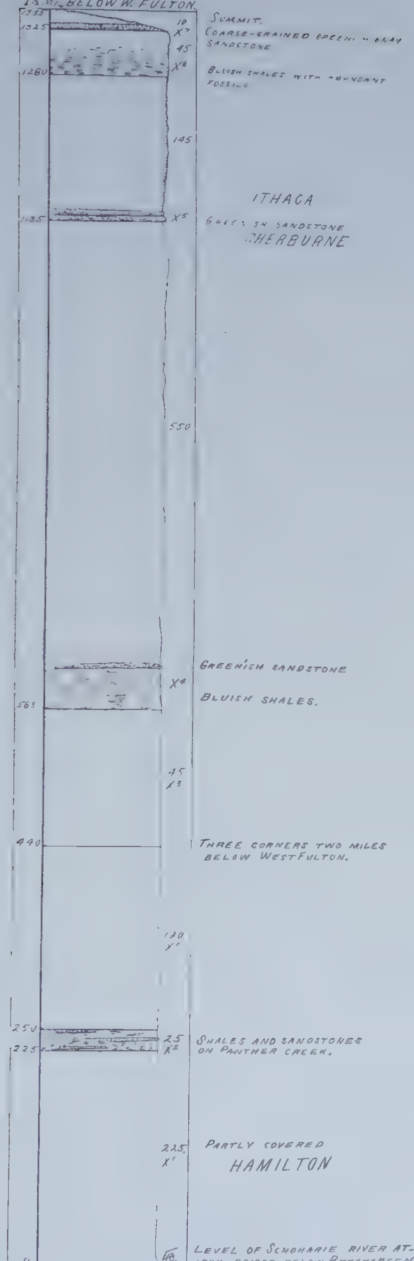
The Sherwood brothers in their Schoharie section give above the Onondaga limestone 25 feet of black slate and shale (nos. 3-5),[a] without correlating it with the Marcellus; but they reported that above these lower black shales 305 feet were covered which would more than include the entire Marcellus formation.

a Proc. Amer. philosophical soc. 17:349.

No. 28, N. SECTION
WEST OF
FULTONHAM
ALONG ROAD TOWARD W. FULTON.



No. 28. X. SECTION OF HILL SOUTH OF PANTHER CREEK 1½ MI. BELOW W. FULTON.



In loose blocks in the Mill creek valley probably carried down by the creek, the following Hamilton species were collected:

1 *Spirifer mucronatus* (Con.) Bill. (a)

Specimens of the very mucronate type.

2 *Chonetes coronata* (Con.) Hall (rr)

3 *Camarotoechia congregata* (Con.) H. & C. (c)

To the southwest of Mill creek is Vroman's Nose which rises some 600 feet above the level of the Schoharie river. The lower part of the southern face has a steep slope largely covered by debris from the upper part of the hill, while the upper portion is a perpendicular cliff composed mainly of coarse, arenaceous shales and sandstones. It is certainly a commanding hill when seen from its foot or at Middleburg, and when seen from the much higher hills to the southwest it looks like a hill blocking the Schoharie valley. A picture of this hill which, unfortunately, like photographs since taken does not give a very distinct impression appears in Emmons' *Agriculture of New York.*[a] The hill was studied in a rather hurried manner but, approximately 250 feet above the river is the base of the rocks which continue for 370 feet to the top of the hill, (A^4). The lower rocks are dark gray shales above which toward the top of the hill are rather blocky shales and thin sandstones. Hamilton fossils occur in the shales in moderate abundance while in some of the coarse, shaly sandstones there are numerous specimens of *Spirophyton* and *Spirifer granulosus* (Con.) H. & C. These rocks all belong in the lower part of the Hamilton formation and according to the Sherwood measured section there are 372 feet exposed in the hill, below which are about 200 feet covered.[b] On the bare sandstone ledge at the summit of the hill are conspicuous glacial striae, some of them quite deep, which run W 10° S.

The following is an approximate section of Vroman's Nose.

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[a] v. 1, plate 6.

[b] Proc. Amer, philosophical society. 17 : 348

SECTION OF VROMAN'S NOSE

XXXVII A

610′		Top of hill Arenaceous shales and sandstones *Hamilton*
		A^4 Shales
250′		
	150′	A^3 Covered
90′		
	15′	A^2 Approximate position of the 15′ of Marcellus shale on Mill creek
75′		
	75′	A^1 Covered
0′		Schoharie river

XXVIII N. A section along the highway from Fultonham toward West Fulton, crossing the northern end of Blenheim hill west of Fultonham, was somewhat hastily studied. This section which is here given is about opposite the one of Moheganter hill on the eastern side of the river. Along the road for some 280 feet outcrops are very rare, then blue shales occur containing specimens of *Chonetes coronata* (Con.) Hall, *Paracyclas lirata* (Con.) Hall and other fossils. From this zone to the summit of the hill the rocks consist of a succession of blue argillaceous shales alternating with sandstones, all of which are apparently in the Hamilton. The highest fossils collected were at 760 feet above the river level and for the succeeding 195 feet the rocks are mostly covered till the summit of the highway is reached where there is a ledge of bluish gray sandstone. Above the road

Plate 8

on the northern side there is a ledge of thin, crossbedded, grayish sandstone. From the river to the road summit is, according to the barometer, 955 feet, which as already stated is apparently all Hamilton. If this correlation and Sherwood's statement that the "top of Vroman's Nose, passes under water at lower end of tow-path road [which is just south of Fultonham]"[a] be correct, then the Marcellus and Hamilton formations on the Schoharie river have a thickness of at least 1670 feet, which, as will be shown later is probably an underestimate rather than an overestimate of their thickness. To the south of the summit of the road, Blenheim hill is considerably higher, perhaps 200 feet, but the writer did not have the opportunity to examine it. The eastern side of Blenheim hill is very steep and rocky and along the tow-path road are cliffs of argillaceous shales and sandstones. The rocks along the highway belong stratigraphically in the lower part of the section from Fultonham west across the northern end of the hill.

XXVIII X. This section is along Panther creek from the Schoharie river to about two miles below West Fulton and then up the hill to the southwest of the creek. For about 90 feet along the lower part of Panther creek the rocks are mostly covered when the foot of the gorge at Bouck's falls is reached. This narrow glen is lined by cliffs of coarse shales and thin sandstones (X^1) which are apparently over 100 feet in hight. Picture rock, on the southern bank a little below the falls is some 85 feet above the creek level at its base; while from the creek level below the falls to the top of the shales under the hotel is approximately 130 feet, or some 220 feet above the Schoharie river level. The gorge is narrow indicating its recent formation and has been cut from rocks of Hamilton age. Some distance farther up the creek and perhaps not much higher than the top of the shales in the cliff at Bouck's falls is the upper end of the gorge. The rocks (X^2) consist of shales and sandstones, some of the latter being quite massive. On the northern side of the creek the exposure is some 25 to 30 feet in hight and is labeled the Blarney

a Proc. Amer. philosophical soc. 17:348.

stone. The dip is apparently heavy, being about 4° S 30° W. Some of the shales contain numerous specimens of *Spirifer granulosus* Con. and other Hamilton fossils. On the under side of a sandstone stratum just above the creek are large numbers of the very mucronate form of *Spirifer mucronatus* (Con.) Bill. associated with *Chonetes coronata* Con. The fossils and the stratigraphic position of the zone show that it is in the Hamilton formation. The species listed below were collected at this locality:

1	*Spirifer granulosus* Con.	(r)
2	*S. mucronatus* (Con.) Bill.	(r)
3	*Tropidoleptus carinatus* (Con.) Hall	(rr)
4	*Camarotoechia prolifica* (Hall) H. & C.	(c)
5	*Nyassa arguta* Hall	(r)
6	*Orthonota undulata* Con.	(rr)
7	*Chonetes coronata* (Con.) Hall	(c)

Above the rocky gorge just described, well toward West Fulton, Panther creek flows in a deep gorge, but the sides are covered with drift, clay and boulders of all sizes so that the bed rocks are concealed. At the three corners, perhaps one and one half miles below West Fulton, the section leaves the valley of Panther creek and follows the highway turning westerly which ascends the steep hill that rises to the south of the creek valley. The road corners, by the barometer, are some 190 feet higher than the glen at X^2 and the slope of the hill for over 800 feet is pretty generally covered by drift. There are a few exposures along the highway in this 800 feet of elevation, as, for example, X^4, 145 feet above the corners where fine, bluish, argillaceous shales and somewhat greenish sandstones occur. Again, 550 feet higher, toward the top of the hill and west of the first road turning to the south, is a ledge of rather coarse grained somewhat greenish gray sandstone (X^5) which has been referred to the Sherburne formation. About 145 feet higher, or by the barometer some 1280 feet above the level of the Schoharie river at the bridge below Breakabeen, are the bluish, argillaceous shales of X^6. This locality is well toward the summit of this part of the plateau and is to the west of the second road turning to the south. It is an

Plate 9

Bouck's Falls. Hamilton

important outcrop, for some of the thin layers of the bluish shales contain abundant specimens of a few species of fossils. *Spirifer mesastrialis* Hall is a common species and this zone is in the Ithaca formation which covers the high part of the plateau to the south of Panther creek and west of the Schoharie river in the southern part of Fulton township. In coarser shales above the bluish ones the fossils are not so common. The following species were collected in a few minutes and a thorough search would undoubtedly materially increase the number:

1	*Spirifer mucronatus* (Con.) Bill.	(a)
2	*S. mesastrialis* Hall	(c)
3	*Orthonota undulata* Con.	(c)
4	*Sphenotus truncatus* (Con.) Hall	(a)
5	*Schizodus appressus* (Con.) Hall	(rr)
6	*S.* cf. *ellipticus* Hall	(r)
7	*Grammysia (Sphenomya) cuneata* Hall (?) Specimens broken and imperfectly preserved.	(r)
8	*Palaeoneilo* cf. *plana* Hall	(rr)
9	*Liopteria bigsbyi* Hall	(r)
10	*Athyris spiriferoides* (Eaton) Hall	(rr)
11	*Orbiculoidea* cf. *media* (Hall) H. & C. The pedicle passage seems to be wider than in the figures of this species and scarcely connected at margin.	(rr)

About 45 feet higher, lacking but 10 feet of the summit on the highway or approximately 1335 feet above the level of the Schoharie river, is a coarse grained somewhat greenish gray sandstone (X^7). On the next ridge to the west, at the same level as X^7, is another outcrop of the coarse grained, massive sandstone on which glacial striae are well preserved, their direction being from the n e toward the s w.

XXVIII Y. Nearly one and one half miles west of West Fulton is a road which turning to the south climbs the steep hill on the southern side of Panther creek. A section was followed along this highway which is about two miles west of XXVIII X and partly parallel to it. The highway bridge across Panther creek near the base of the steep hill is approximately 280 feet above the level of

the creek in West Fulton. The rocks wherever exposed along the lower slopes of the hills bordering this part of the course of Panther creek are clearly of Hamilton age. On the highway 375 feet above the bridge, or 655 feet above West Fulton are coarse, irregular, bluish shales, (Y^3) which contain plenty of fossils. The species so far as noted in a hasty examination are Hamilton and this zone is considered to be near the top of the Hamilton formation. About 85 feet higher, or approximately 1190 feet above the Schoharie river, is a prominent outcrop of massive, greenish gray to bluish sandstone (Y^5) on the highway leading south well toward the corners. The sandstone is quite coarse grained, some 15 feet being exposed, and one layer shows ripple marks. This zone is referred to the Sherburne formation, and it will be recalled that a similar sandstone in the section to the east (X^5) 1135 feet above the Schoharie river was also considered as in this formation. Some 195 feet higher on the main east and west road on top of the plateau is a ledge of thin bedded sandstones (Y^7). This ledge crosses the highway just west of schoolhouse no. 6, in a straight line about two and one half miles southwest of West Fulton, approximately 950 feet higher and is at about the summit of this part of the plateau. The sandstones are moderately fossiliferous, *Spirifer mesastrialis* Hall (?) being the most common species. The rocks belong in the Ithaca formation, which, as stated in the description of section X covers the high part of the plateau to the south of Panther creek. The following species were collected:

1 *Spirifer mesastrialis* Hall (?) (c)
Too imperfectly preserved to show whether there are fine striae or not.

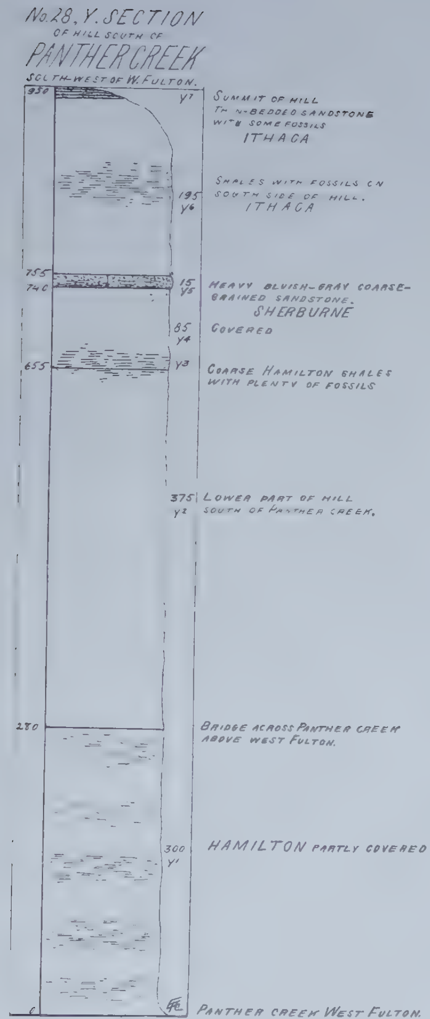
2 *Palaeoneilo emarginata* (Con.) Hall var. (r)
The form with only a faint posterior constriction.

3 *Bellerophon patulus* Hall (rr)

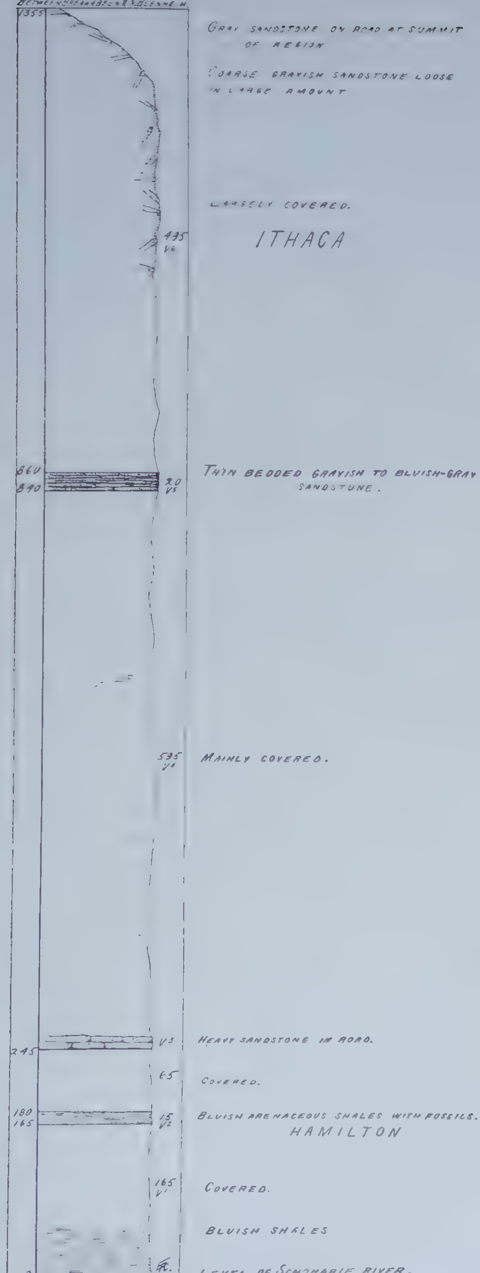
4 *B. acutilira* Hall (?) (rr)

5 *Cyrtolites (Cyrtonella) pileolus* Hall (?) (rr)
Imperfectly preserved.

6 *Pectinidae* sp. (rr)
Too imperfect for generic identification.


No. 28, Y. SECTION
OF HILL SOUTH OF
PANTHER CREEK
SOUTH-WEST OF W. FULTON.
950
Y7
SUMMIT OF HILL
THIN-BEDDED SANDSTONE
WITH SOME FOSSILS
ITHACA
195
Y6
SHALES WITH FOSSILS ON
SOUTH SIDE OF HILL.
ITHACA
755
740
15
Y5
HEAVY BLUISH-GRAY COARSE-
GRAINED SANDSTONE.
SHERBURNE
85
Y4
COVERED
655
Y3
COARSE HAMILTON SHALES
WITH PLENTY OF FOSSILS
375
Y2
LOWER PART OF HILL
SOUTH OF PANTHER CREEK.
280
BRIDGE ACROSS PANTHER CREEK
ABOVE WEST FULTON.
300
Y1
HAMILTON PARTLY COVERED
0
PANTHER CREEK WEST FULTON.

No. 28. V. SECTION
ON WESTERN SIDE OF
SCHOHARIE RIVER



XXVIII W[1]. Perhaps one half mile farther west and some 170 feet lower along the banks of a brook to the south of the road is a good exposure of bluish, argillaceous shales. Stratigraphically these shales belong in the lower part of the covered interval of Y[6] and being in the Ithaca formation indicate that the greater part of the zone Y[6] belongs in that formation. The species found at this locality are the following:

1	*Spirifer mucronatus* (Con.) Bill. Some of the specimens are very wide and mucronate.	(c)
2	*Spirifer mesastrialis* Hall	(rr)
3	*S. fimbriatus* (Con.) Bill.	(rr)
4	*Ambocoelia umbonata* (Con.) Hall (?) Imperfectly preserved.	(rr)
5	*Sphenotus truncatus* (Con.) Hall	(rr)
6	*Paracyclas tenuis* Hall	(rr)
7	*Liopteria dekayi* Hall	(rr)
8	*Goniophora* sp. Only posterior part of specimen preserved.	(rr)
9	*Tentaculites* sp.	(rr)
10	*Grammysia subarcuata* Hall	(rr)
11	Crinoid segments	

In the above section, if the top of the Hamilton formation has been correctly located at Y[3] then it gives information upon which an estimate of the thickness of the Marcellus and Hamilton formations may be made. The barometer made West Fulton about 450 feet above the Schoharie river level, while in Sherwood's section the thickness of the rocks from the top of the Helderberg limestone to the base of Wauhalla mountain, which is about opposite the mouth of Panther creek, is given as 920 feet[a]. This gives 920+450+655=2025 feet minus the amount of dip from the mouth of Panther creek to the bridge across the creek west of West Fulton for the thickness of the Marcellus and Hamilton formations. If in section XXIX A east of Breakabeen and Wauhalla mountain the zone A[9], 585 feet above the Schoharie river, marks the top of the Hamilton then it is approximately 485 feet lower than in the section XXVIII Y and since the distance between the two locali-

[a] Proc. Amer. philosophical soc., 1878, 17 :348-49.

ties is six miles it would give a dip to the southeast of approximately 80 feet a mile. The distance from the mouth of Panther creek to the bridge west of West Fulton is four and one fourth miles and if the dip for that distance is some 80 feet a mile e s e then the thickness of the Marcellus and Hamilton formations is 2025—340 feet which equals 1685 feet.

XXVIII C. From West Fulton a section was followed up Panther creek to its head in the western part of Fulton township and then to the summit of the divide in the eastern part of Summit township. Rather more than one half mile west of the village is a small quarry on the northern side of the highway which has furnished a part of the foundation stone used in West Fulton and there are also layers of blue flagging stone of fair quality. Some of the rather irregular sandstones contain numerous specimens of *Spirifer granulosus* (Con.) H. & C. associated with other Hamilton species. The quarry's elevation above Panther creek at West Fulton was not determined, but it is clearly several hundred feet below the top of the Hamilton formation in the lower part of the zone called C^1 of this section.

Three and one fourth miles w n w of West Fulton in school district no. 7 the main branch of Panther creek turns sharply to the north; but the section follows the highway toward Summit and the smaller branch of the creek up the hill to the west. Some 490 feet higher than West Fulton, on the south side of the road after crossing the west branch of Panther creek and passing the road on which the schoolhouse is located, are quite thin, bluish, argillaceous shales (C^2) certain layers of which contain abundant specimens of the very mucronate form of *Spirifer mucronatus* (Con.) Bill. associated with *Chonetes coronata* (Con.) Hall. These shales are clearly in the Hamilton formation. The following species were collected:

1	*Chonetes coronata* (Con.) Hall	(a)
2	*Spirifer mucronatus* (Con.) Bill.	(a)
3	*Cyrtina hamiltonensis* Hall	(rr)
4	*Camarotoechia congregata* (Con.) H. & C.	(rr)
5	*Macrodon hamiltoniae* Hall (?) Imperfectly preserved.	(rr)
6	*Orthonota undulata* Con.	(rr)
7	*Prothyris lanceolata* Hall	(rr)

For 50 feet the hillside is covered when another outcrop of coarser and more arenaceous shales (C³) is reached which also contains abundant Hamilton fossils. The shales are capped by very thin bedded, even sandstones and the zone is clearly in the Hamilton:

1	*Spirifer granulosus* (Con.) H. & C.	(rr)
2	*S. audaculus* (Con.) H. & C.	(c)
3	*Camarotoechia congregata* (Con.) H. & C.	(c)
4	*Pterinea flabella* (Con.) Hall	(rr)
5	*Liopteria bigsbyi* Hall (?)	(r)
	Broken and poorly preserved.	

On the hillside 55 feet above C³, or approximately 595 feet higher than West Fulton, are thin, bluish gray sandstones (C⁴) in which a few fossils occur. This ledge is about on a level with the small cemetery on the north side of the road, and is apparently in the Hamilton formation. 40 feet higher is a ledge of thin bedded, bluish gray sandstone five feet in thickness. A little below this stratum are loose fossils which seem to have come from this outcrop and apparently show its Hamilton age. At the edge of the woods on the south side of the road are ledges of rather coarse grained, thin bedded, grayish sandstone (C⁵). There are from 15 to 20 feet of these sandstones exposed, which apparently occur on the north side of the road at a little higher elevation. No fossils were found except plant stems; but there are numerous clay pebbles in some of the layers. This zone is probably near the dividing line between the Hamilton and Sherburne formations and it is a matter of some uncertainty to which formation it should be referred. On the highway 50 feet higher or 825 feet above West Fulton are bluish to greenish argillaceous shales (C⁶) and bluish gray flagging stone. No fossils were found and in lithological characters these rocks closely resemble those of the Sherburne formation to which they are referred. Just south of the turn on the first road turning south toward Eminence are thin bedded, bluish gray, flagging stones (C⁷) below which are smooth, bluish, argillaceous shales weathering to an olive tint and containing some concretionary nodules. These shales are about 45 feet above those of C⁶.

On the highway one and one fourth miles east of Summit, in the eastern part of Summit township, on the divide, is a layer of rather irregular sandstone (C⁸) which contains a few fossils.

There are also fossils in bluish, argillaceous shales occurring just above the sandstone. On each side of the summit 20 feet below the fossiliferous sandstone are smooth, bluish shales which weather olive and some grayish green flagging stone in which fossils were not found. This fossiliferous zone is regarded as indicating the appearance of the Ithaca fauna, succeeding the barren sandstones and shales of the Sherburne formation and it is referred to the Ithaca formation although the hasty search for fossils did not yield specimens of *Spirifer mesastrialis* Hall. The list of fossils is as follows:

1	*Spirifer mucronatus* (Con.) Bill.	(c)
2	*S. tullius* Hall	(r)
3	*Tropidoleptus carinatus* (Con.) Hall	(r)
4	*Microdon (Cypricardella) bellistriatus* Con.	(rr)
5	*M. (C.) gregarius* Hall	(rr)
6	*Sphenotus cuneatus* (Con.) Hall	(rr)
7	*Schizodus appressus* (Con.) Hall	(rr)

On the south side of the road farther east near the Summit-Fulton township line along the upper course of one of the branches of the Westkill are coarse, grayish sandstone and thinner blue shales (C^S—). This ledge is 140 feet lower than the fossiliferous zone of C^S and is propably near the top of the Hamilton. Fossils occur rather sparingly, the three following species having been collected during a few minutes search:

1	*Tropidoleptus carinatus* (Con.) Hall	(r)
2	*Spirifer* sp. Fragments.	(rr)
3	*Nuculites oblongatus* Con. Large specimen—35 mm long and 19 high.	(rr)

On the western side of the divide going down into the second valley, sandstone and coarse shales containing abundant Hamilton fossils were found 120 feet below the zone C^S. Between the two fossiliferous zones are exposures of sandstones and smooth bluish to olive shales which closely resemble, lithologically, those of the typical Sherburne formation. To the north of the road and northeast of Summit is a high, rounded hill, known as Cobble hill, on which are plenty of these fine shales, the Sherburne formation apparently capping the hill.

The section described above may be represented diagrammatically in the following manner:

SECTION UP PANTHER CREEK TO THE DIVIDE WEST OF WEST FULTON

XXVIII C

950′		Divide on road $1\frac{1}{4}$ miles east of Summit
945′		C^8 Shales and sandstones containing fossils *Ithaca*
	75′	
870′		C^7 Bluish to olive shales and sandstones on Eminence road
	45′	
825′		C^6 Greenish shale and thin bedded sandstone *Sherburne*
	50′	
775′		
	20′	C^5 Thin bedded, grayish sandstone
755′		
	115′	Covered
640′		
	5′	Bluish-gray sandstone; loose fossils *Hamilton*
635′		
	40′	C^4
595′		Thin sandstones with a few fossils
	55′	
540′		C^3 Coarser Hamilton shales
	50′	
490′		C^2 Fine Hamilton shales
	490′	C^1
		Quarry $\frac{1}{2}$ mile west of West Fulton *Hamilton*
0′		Panther creek at West Fulton

The elevations in the above section, although obtained by means of a barometer, are considered fairly accurate for geological purposes, since on comparing the elevation of a certain horizon of this section above sea level with that of Summit hill whose altitude was determined by the New York survey under Gardiner it was found that the estimated altitude of the section was only 70 feet too great. In estimating the altitude of the section above sea level Guyot's elevations of the Schoharie valley were used[a] which were obtained by means of a mercurial barometer; while from the mouth of Panther creek to the top of the hill east of Summit, the measurement was made by means of an aneroid.

On comparing the altitude of the fossils found at XXVIII C^8—which are thought to come from about the top of the Hamilton, with that of the highest Hamilton zone in the Summit hill section it is found that the Summit fossils are 300 feet higher, or 370 feet if the correction mentioned above be made. The distance between the two localities is two miles which gives a dip of from 150 to 185 feet a mile to the southeast. If the above calculation be correct and this strong southeasterly dip continues to the Schoharie river, then the thickness of the rocks in any section continuing westerly for several miles based upon the altitude would be too great. This is probably the case for the one just described up the Panther creek from West Fulton and the altitudes of the section are greater than the thickness of the rocks represented in it.

Blenheim

Blenheim township lies to the south of Fulton and to the east of Summit and Jefferson. Its eastern part is crossed by the Schoharie river bordered on the east by a very steep hill which in places has almost perpendicular walls several hundred feet in hight. The central part of the township is crossed from the west toward the east by two streams known as the Westkill and Mill creek which unite near North Blenheim and

[a] Am. jour. science, 3d ser., 19:449.

enter the Schoharie river at that locality. Both of these creeks have cut deep valleys, specially in their lower courses.

XXVIII V. This section begins near the level of the Schoharie river, two and one half miles south of Bouck's falls, or about half the distance from Panther creek to North Blenheim, and follows the highway along the Fulton-Blenheim boundary to the northwest. Along the river road are smooth, bluish shales (V^1) which contain very few fossils although they are shown by the overlying rocks to be in the Hamilton formation. Just above the first house on the road leading up the hill to the southwest in the southern part of Fulton township is an exposure of 15 feet of bluish, arenaceous, quite fossiliferous shales (V^2), approximately 165 feet above the level of the river. The shales contain a Hamilton fauna in which formation this zone belongs and the following species were collected:

1 *Camarotoechia prolifica* (Hall) H. & C. (aa)
Very abundant in thin layers.

2 *Spirifer audaculus* (Con.) H. & C. (?) (rr)
Imperfectly preserved.

3 *Ambocoelia umbonata* (Con.) Hall (rr)

4 *Strophalosia truncata* (Hall) Beecher (?) (r)

5 *Paracyclas lirata* (Con.) Hall (rr)

6 *Orthonota* (?) *parvula* Hall (rr)

7 *Nyassa arguta* Hall (rr)

8 *Pterinea flabella* (Con.) Hall (rr)

9 *Actinopteria boydi* (Con.) Hall (rr)

A massive sandstone (V^3) crosses the road 65 feet above the shales and runs along the highway to the northwest for some two and one half miles to a point near the first road turning to the north, the bed rock being mostly concealed by drift. According to the barometer the top of this concealed interval is 595 feet above the massive sandstone of V^3, although on account of the southeast dip as shown above, it is not probable that the concealed rocks have this thickness. Just below the first turn to the north are ledges of rather thin bedded, coarse grained, grayish to bluish gray sandstone, 20 feet of which are exposed.

No fossils were found. It is uncertain in which formation this ledge belongs and on account of the great thickness of the concealed rocks it is impossible to indicate the approximate line of division between the different formations. For nearly 500 feet above the sandstone ledge of V^5 the bed rocks are largely concealed although there are occasioned exposures of sandstones. At this elevation, approximately 1350 feet above the level of the Schoharie river, the summit of this section is reached and the land is about as high as any in this general region except to the south where the spurs of the Catskill mountains are conspicuous toward Stamford. On the surface are large numbers of loose blocks of coarse grained, grayish sandstone but no pieces of red rock were seen. Some of the sandstone is of greenish gray color, similar in appearance to the Oneonta formation and like the sandstone which will be described later, near the top of the hill west of North Blenheim and four miles southeast of this locality. The general features are shown in the diagrammatic section reproduced herewith.

About two and one quarter miles west of the summit of the above section is the village of Eminence on the western line of Blenheim and at the corners of Summit and Jefferson townships. To the east of the village and some 50 feet higher is a rounded highland which forms the top of section XXVIII V. Between the two hills is a deep and narrow valley formed by the main northern branch of the Westkill. Capping the hill is a ledge of thin bedded, coarse grained, grayish to greenish gray sandstone, six feet or more showing in the outcrop. No fossils were found and the rock considerably resembles coarse layers seen in the Ithaca to the east of the Schoharie valley, or even in the Oneonta. No red rocks in the ledge or even loose pieces were seen. This hill is about two and one quarter miles southwest of the Ithaca shales of XXVIII W^1 and four and one half miles northwest of the coarse sandstone (XXVIII D^5) which caps the hill to the west of North Blenheim. One barometric reading gives the summit of the Eminence hill as 1200 feet above the level of the Schoharie river

Plate 30

at North Blenheim, while the coarse sandstone D^5 west of North Blenheim is 650 feet above the river level. If these two zones represent about the same horizon then there is a dip of approximately 122 feet a mile to the southeast.

XXVIII D^1. To the west of North Blenheim is a steep hill between the Westkill and Mill creek. The rocks exposed in the gorge at the lower end of the Westkill and in the eastern end of this hill form an interesting section, passing from the Hamilton formation at the base to the coarse grained, greenish sandstones near the top similar to the Oneonta. In the Schoharie river at North Blenheim are coarse, grayish sandstones which do not closely resemble the Hamilton although they are probably in that formation. Some 30 feet above the river is the foot of the gorge in the lower part of the Westkill at the falls. The sides of the gorge are perhaps 50 feet in hight and the rocks consist of sandstone alternating with shales of olive, blue and greenish color. In the blue and olive shales below the falls are numerous specimens of *Paracyclas tenuis* Hall, and (?) *Beyrichia* sp. is also common. This exposure resembles the Sherburne formation in lithologic appearance; but 25 feet higher are blue shales containing a number of Hamilton species so that it is perhaps better to regard this zone as one of the transitional beds from the Hamilton to the Sherburne formation. Mather mentioned the fossils at this locality stating that "The gray grits by the falls at the tannery, at North Blenheim, contain fossil shells. They were first observed by Prof. Vanuxem, who found their stratum about six inches thick. Several localities were observed where many species of fine shells may be obtained, in the bluish and brownish gritty shales on the road from North Blenheim to Gilboa."[a]

Mather also indicated the top of the Hamilton on his section "up the valley of Schoharie creek" as near North Blenheim and succeeded by the Portage group.[b] This is about the same classification as that indicated above, since the writer regards the

[a] Geology of New York, 1843, pt 1, p. 322-23.
[b] Ibid., pl. 25, fig. 6.

Sherburne formation of eastern New York as synchronous with the lower part of the Portage of western New York.

XXVIII D². In the ledges by the side of the highway leading up Mill creek only a short distance above the bridge, are thin sandstones alternating with blue, arenaceous shales, in both of which are numerous specimens of *Tropidoleptus carinatus* (Con.) Hall associated with a smaller number of specimens of other species. The complete list is:

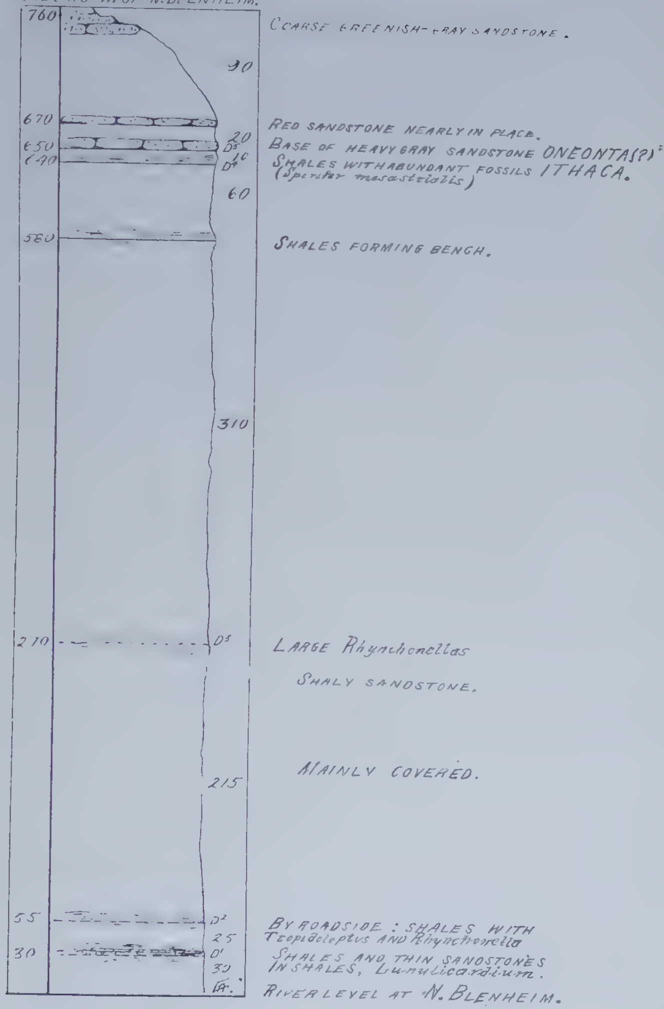
1 *Tropidoleptus carinatus* (Con.) Hall (a)
2 *Chonetes coronata* (Con.) Hall (?) (rr)
3 *Ambocoelia umbonata* (Con.) Hall (rr)
4 *Camarotoechia congregata* (Con.) H. & C. (c)
One specimen resembles somewhat *C. stevensi* (Hall) H. & C.
5 Cephalopod (rr)
Fragment of shell.

The above fossiliferous zone is 25 feet above the base of the Westkill gorge and shows the transitional nature of the beds in the lower part of this section.

XXVIII D³. In ascending the eastern point of the hill for 215 feet above the shales by the highway the rocks are largely covered. At an elevation of 270 feet above the river level, however, are plenty of loose, angular shales which evidently came from a ledge at about that horizon. These shales are quite fossiliferous containing a large number of specimens of *Camarotoechia stevensi* (Hall) H. & C. and an occasional one of *Spirifer mesastrialis* Hall. These fossils show that at this horizon the rocks of the Ithaca group are reached. The complete fauna is:

1 *Camarotoechia stevensi* (Hall) H. & C. (aa)
Very abundant in a thin rotten sandstone.
2 *Spirifer mucronatus* (Con.) Bill. (?) (rr)
3 *S. mesastrialis* Hall (rr)
The fine striae are only faintly shown.
4 *Sphenotus cuneatus* (Con.) Hall (a)
5 *Goniophora carinata* (Con.) Hall (rr)
6 *Modiomorpha* sp. (r)

No. 28. D. SECTION OF HILL BETWEEN WEST KILL & MILL CREEKS W. OF N. BLENHEIM.



7 *Palaeoneilo* cf. *plana* Hall (rr)

8 *Lingula* sp. (rr)

9 *Grammysia* cf. *elliptica* Hall (rr)

Similar to the specimen from Ithaca, N. Y., as figured on pl. 58, fig. 1.

10 cf. *Glossites depressus* Hall (rr)

11 *Bellerophon* sp. (rr)

Fragment of a very large specimen showing a strong mesial band with a deep sinus at the front of the shell.

12 *Tentaculites spiculus* Hall (c)

Another bench of shales occurs 310 feet above D^3 and at this horizon quite a number of species were collected from the loose pieces though it is not certain that all of them came from this zone. The list follows:

1 *Camarotoechia stevensi* (Con.) Hall (?) (c)

2 *Spirifer mucronatus* (Con.) Bill. (?) (rr)

Poorly preserved.

3 *S.* *mesastrialis* Hall (r)

Most of the specimens are worn and do not show the fine striae, but on the dorsal fold of one they are clearly shown.

4 *S.* sp. (rr)

In form and size of plications like *Sp. granulosus* (Con.) Hall, but too imperfectly preserved to show granules.

5 Crinoid stems. (r)

Segments of small ones.

6 *Dalmanites* (*Crypheus*) *boothi* (Green) Hall (rr)

7 *Microdon* (*Cypricardella*) *tenuistriatus* Hall (rr)

8 *Nyassa arguta* Hall (c)

Same at least as fig. 7 and 8, pl. 53, from Pitcher Springs, which is in the Ithaca group.

9 *Sphenotus truncatus* (Con.) Hall (c)

These range from 10 to 20 mm in length and are apparently quite good specimens of this species.

10 *Goniophora hamiltonensis* (Hall) Miller (?) (r)

Not clearly preserved but apparently this species.

11 *Palaeoneilo constricta* (Con.) Hall
var. *flexuosa* Hall (rr)

12 *Leptodesma* cf. *rogersi* Hall (c)
The specimens being poorly preserved do not show the spine and do not seem to be quite so oblique on the umbonal ridge.

13 (?) *Schizodus* sp. (rr)
Badly broken.

14 *Liopteria dekayi* Hall (rr)

15 *Orbiculoidea* sp. (rr)
Broken and poorly preserved.

On the supposition that this zone and that of XXVIII X^6 on the hill south of West Fulton are at about the same horizon, near the base of the Ithaca formation, a calculation was made which gave a dip of 174 feet a mile to the south southwest. Again the same calculation was made between this zone and that of XXVIII C^8 on the hill east of Summit which gave a dip of 129 feet a mile to the southeast.

It will be noticed that this dip of 129 feet a mile agrees very closely with that obtained for the sandstone of the Eminence hill and D^5 of this section which is 122 feet. The general agreement of these several localities seems to demonstrate that this portion of Schoharie co. has a considerable southeast dip.

XXVIII D^4. A ledge of rather thin shales in which fossils are abundant occurs 640 feet above the level of the river. *Spirifer mesastrialis* Hall and other species of the Ithaca formation were found and the entire list is as follows:

1 *Sphenotus cuneatus* (Con.) Hall (c)

2 *Orthonota undulata* Con. (rr)

3 *Schizodus appressus* (Con.) Hall (?) (c)
Rather smaller though near the form of this species.

4 *Grammysia* (*Sphenomya*) *cuneata* Hall (rr)

5 *Leptodesma rogersi* Hall (c)

6 *Liopteria dekayi* Hall (r)

7 *L.* sp. (r)
Fine concentric striae.

8 *Spirifer mesastrialis* Hall (r)

9 *Liorhynchus mesacostalis* Hall (?) (rr)

10 *Orbiculoidea* sp. (rr)

11 *Tentaculites* sp. (r)

XXVIII D^5. Only 10 feet above this terrace of the Ithaca shales is a ledge of gray, coarse grained, thin bedded sandstone with the lithologic appearance of the Oneonta. 20 feet above its base red sandstone was found which was thought to come from a stratum at about that horizon but perhaps this is not the case. There is, however, some positive support for the supposition that this red sandstone is nearly in place since at Gilboa in the Schoharie river are red sandstones and shales which according to Sherwood's section are 666 feet above the gray sandstone which makes the rapids in the river at North Blenheim[a]; while the red sandstone on the hill west of North Blenheim is approximately 670 feet above the same horizon. 90 feet above the red sandstone is a cliff of massive coarse grained, greenish sandstone, forming the eastern end of the hill, at an altitude of 760 feet above the river level. This sandstone in its lithologic appearance closely resembles the Oneonta although it probably occurs at a lower horizon than the sandstone farther west in Jefferson township which has been called the base of the Oneonta formation.

XXVIII H^2. This section follows the highway from North Blenheim toward Jefferson along the side of the steep hill to the north of Mill creek and is nearly parallel to the section just described. The exposures for the lower part of it are about the same as those for XXVIII D, above which the rocks are covered for a considerable thickness, and this part is called H^1. At 440 feet above the river a heavy bedded, quite coarse grained, massive, greenish gray sandstone is reached (H^2), 30 feet of which is shown in the highway and this is succeeded by 35 feet of greenish and bluish, smooth, argillaceous shales (H^3). No fossils were found either in the sandstone or the shales. The elevation of this sandstone, 440 feet above the river, agrees closely with the thickness of 431 feet assigned by Sherwood to the rocks from the rapids at North Blenheim (formerly Patchin Hollow) to the coarse gray sandstone which forms the top of the Little

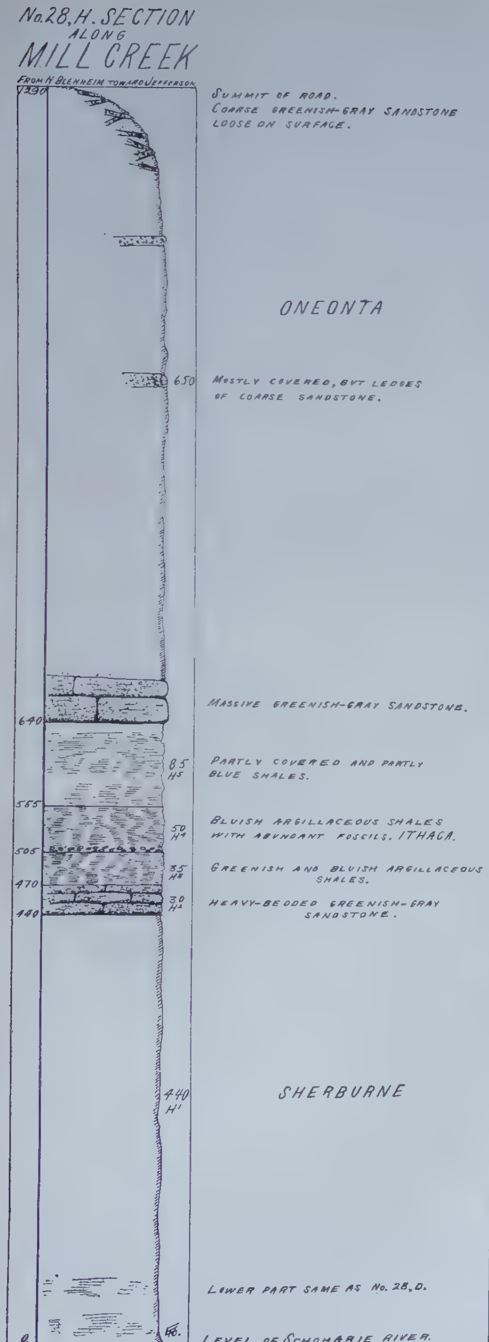
[a] Proc. Amer. philosophical society, 17:347-48.

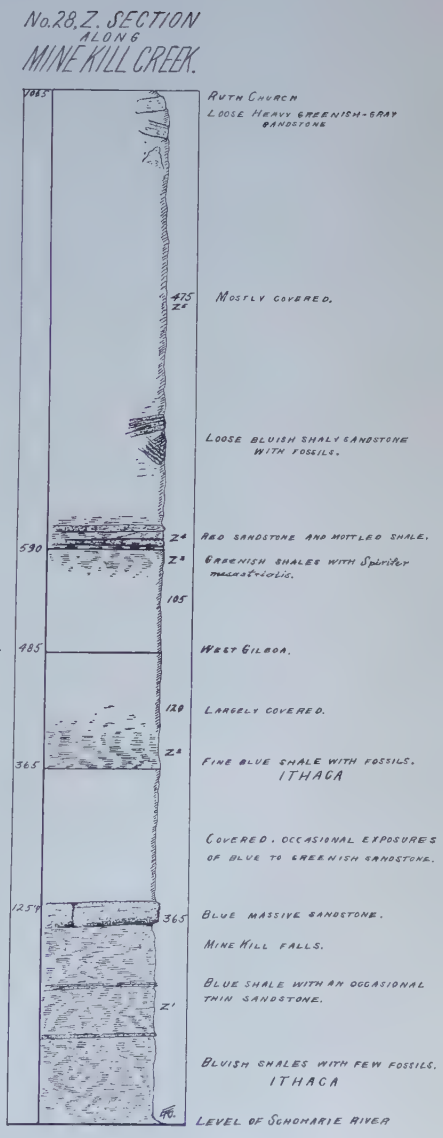
Manorkill[a] (this is supposed to be the falls generally called the Minekill).

XXVIII H^4. On top of the smooth, argillaceous shales of H^3 is a layer with pebbles making a sort of conglomerate in which fossils are common. Succeeding this layer are bluish, argillaceous shales which also contain numerous fossils. Some of the layers in the shale are somewhat calcareous, containing abundant specimens of *Tropidoleptus carinatus* (Con.) Hall, and form a sort of fire-stone. These shales constitute one of the most fossiliferous zones found in the Ithaca formation and it is an excellent locality for collecting. It will be farther seen on referring to the list of 42 species recorded from this zone that it is practically Hamilton and furnishes an interesting example of the recurrence of this fauna. *Spirifer mesastrialis* Hall was not noticed in this zone, but in section XXVIII D this species was found some 235 feet lower and also higher. The fauna is interesting and richer than that found at any other locality.

1	*Spirifer mucronatus* (Con.) Bill.	(a)
2	*S. tullius* Hall	(c)
3	*S. granulosus* (Con.) H. & C.	(r)
4	*Tropidoleptus carinatus* (Con.) Hall	(a)
5	*Athyris spiriferoides* (Eaton) Hall	(c)
6	*Chonetes setigera* Hall	(a)
7	*C. coronata* (Con.) Hall	(r)
8	*Cryptonella (Eunella) lincklaeni* Hall	(r)
9	*Palaeoneilo maxima* (Con.) Hall	(c)
10	*P. emarginata* (Con.) Hall	(rr)
11	*Pholadella radiata* (Con.) Hall	(c)
12	*Nucula bellistriata* (Con.) Hall	(rr)
13	*Glyptodesma erectum* (Con.) Hall	(c)
14	*Orthonota undulata* Con.	(r)
15	*Modiomorpha concentrica* (Con.) Hall	(rr)
16	*M. mytiloides* (Con.) Hall	(rr)
17	*M. subalata* (Con.) Hall var. *chemungensis* Hall	(rr)

[a] Proc. Amer. philosophical society, 17:347-48.


No.28, H. SECTION
ALONG
MILL CREEK
FROM N. BLENHEIM TOWARD JEFFERSON
1290
SUMMIT OF ROAD.
COARSE GREENISH-GRAY SANDSTONE
LOOSE ON SURFACE.
ONEONTA
650
MOSTLY COVERED, BUT LEDGES
OF COARSE SANDSTONE.
MASSIVE GREENISH-GRAY SANDSTONE.
640
85
H5
PARTLY COVERED AND PARTLY
BLUE SHALES.
555
50
H4
BLUISH ARGILLACEOUS SHALES
WITH ABUNDANT FOSSILS. ITHACA.
505
35
H3
GREENISH AND BLUISH ARGILLACEOUS
SHALES.
470
30
H2
HEAVY-BEDDED GREENISH-GRAY
SANDSTONE.
440
SHERBURNE
440
H1
LOWER PART SAME AS No. 28, D.
0.
LEVEL OF SCHOHARIE RIVER.


No.28, Z. SECTION
ALONG
MINE KILL CREEK.
1085
RUTH CHURCH
LOOSE HEAVY GREENISH-GRAY
SANDSTONE
475
Z5
MOSTLY COVERED.
LOOSE BLUISH SHALY SANDSTONE
WITH FOSSILS.
Z4
RED SANDSTONE AND MOTTLED SHALE.
590
Z3
GREENISH SHALES WITH Spirifer
mesastrialis.
105
485
WEST GILBOA.
120
LARGELY COVERED.
Z2
365
FINE BLUE SHALE WITH FOSSILS.
ITHACA
COVERED. OCCASIONAL EXPOSURES
OF BLUE TO GREENISH SANDSTONE.
125'?
365
BLUE MASSIVE SANDSTONE.
MINE KILL FALLS.
BLUE SHALE WITH AN OCCASIONAL
THIN SANDSTONE.
Z1
BLUISH SHALES WITH FEW FOSSILS.
ITHACA
LEVEL OF SCHOHARIE RIVER

18 *Goniophora hamiltonensis* (Hall) Miller (c)
Imperfectly preserved.
19 *G. rugosa* (Con.) Miller (rr)
20 *Nuculites triqueter* Con. (rr)
21 *N. oblongatus* Con. (rr)
22 *Grammysia subarcuata* Hall (rr)
23 *G. arcuata* (Con.) Hall (rr)
24 *G. globosa* Hall (rr)
25 *Actinopteria boydi* (Con.) Hall (rr)
26 *A. decussata* Hall (rr)
27 *Bellerophon acutilira* Hall (r)
Crushed and imperfectly preserved.
28 *Coleolus tenuicinctum* Hall (rr)
29 *Phacops rana* (Green) Hall (rr)
30 *Dalmanites (Crypheus) boothi* (Green) Hall (r)
31 *Orthis (Rhipidomella) vanuxemi* Hall (?) (rr)
32 *Orthothetes chemungensis* (Con.) H. & C. (rr)
33 *Chonetes lepida* Hall (r)
34 *Solen (Palaeosolen) siliquoidea* Hall (rr)
35 *Microdon (Cypricardella) bellistriatus* Con. (?) (rr)
Imperfectly preserved.
36 *M. (Cypricardella) tenuistriatus* Hall (c)
37 *Macrodon hamiltoniae* Hall (rr)
38 *Cimitaria recurva* (Con.) Hall (rr)
39 *Hyolithes aclis* Hall (rr)
40 *Leda diversa* Hall (rr)
41 *Cyrtolites (Cyrtonella) pileolus* Hall (rr)
42 *Pleurotomaria rotalia* Hall (rr)

XXVIII H^5. Succeeding these fossiliferous shales for 85 feet the rocks are partly covered; but there are not infrequent exposures of blue shales. Fossils were not found. The examination was hastily made and the shales are undoubtedly fossiliferous as are those of the same general horizon in XXVIII D^4 which contain specimens of *Spirifer mesastrialis* Hall. These blue shales show within 10 or 15 feet of the base ledges of coarse grained, irregular, thin bedded, grayish to greenish gray sandstone (H^6) which

weathers to a light gray color and resembles in lithologic appearance the Oneonta sandstone. The base of this ledge is barometrically 640 feet above the Schoharie river, which is only 10 feet lower than that of the similar ledge in section XXVIII D[5]. On the surface not far above the base are loose blocks of red sandstone, but it was not found in place. Along the road to the west the rocks are largely covered on the high ground in the western part of Blenheim and eastern part of Jefferson. But at the summit of the road in the eastern part of Jefferson there is plenty of the coarse, greenish gray sandstone loose on the surface and the long lines of stone walls are constructed largely of it. In altitude this locality is barometrically some 650 feet above H[6] or 1290 feet above the Schoharie river at North Blenheim; but if there be a dip of 80 feet a mile to the south of east, as along Panther creek, then the thickness of the rocks would not be more than 350 feet for this upper part of the section.

XXVIII E[1]. By the side of the river road about one and one half miles south of North Blenheim and 345 feet higher are bluish, argillaceous shales which are fairly fossiliferous. They contain specimens of:

1	*Spirifer mucronatus* (Con.) Bill.	(rr)
2	*Chonetes setigera* Hall	(rr)
3	*Tropidoleptus carinatus* (Con.) Hall	(rr)
4	*Grammysia* sp.	(rr)

Only fragments.

XXVIII B[1]. On the eastern side of the Schoharie river below North Blenheim and in the northeastern part of the township is a precipitous wall of rock out of which the highway has been cut; a locality known as the "dugway." The rocks consist of soft, blue, argillaceous shales with thin layers of sandstone. The irregular layers of shales contain some rather poorly preserved fossils; but the smooth shales seem to be barren. Toward the top of the cliff is a layer which has somewhat concretionary structure, similar to that noted in other localities in the upper Hamilton and succeeding formations. This cliff is shown to be

in the Hamilton formation both by the fossils in the rocks on the western side of the river at XXVIII V², which at 165 feet above the river are not far below this locality, and by those which occur in the shales.

1	*Camarotoechia prolifica* Hall Abundant in a thin layer.	(a)
2	*Nuculites oblongatus* Con.	(rr)
3	*Palaeoneilo constricta* (Con.) Hall	(rr)
4	*Phthonia sectifrons* (Con.) Hall	(rr)
5	*Orthonota* (?) *parvula* Hall	(rr)
6	*Pholadella radiata* (Con.) Hall	(rr)
7	*Grammysia arcuata* (Con.) Hall	(rr)
8	*G. lirata* Hall	(rr)
9	*Pterinopecten vertumnus* Hall	(c)
10	*Bellerophon patulus* Hall (?)	(rr)

In the Schoharie river valley region the line of separation between the Hamilton and Sherburne formations is not as clearly shown for part of the distance as it generally is farther west. This is due largely to the heavy mantle of drift covering the slopes of part of the hills, also the valley near North Blenheim where the characters of the two formations blend. It was shown pretty clearly, however, in Fulton township that the line of division is well toward the top of the high hill south of Panther creek which is followed to the upper part of the high hill west of the Schoharie river. Then the line is along the side of this hill dipping quite rapidly to the south and reaching the river valley in the vicinity of North Blenheim and apparently crossing the river somewhat south of that village. Then it gradually rises on the slope of the hill east of the river as it is followed northerly till opposite Breakabeen we find it on the hill to the east and above Houston Corners. From there it continues northerly to the Moheganter hill in the southern part of Middleburg, enters the northwestern part of Broome township and follows the western side of Catskill creek for some distance below Franklinton before it crosses to the eastern side.

Gilboa

To the south and east of Blenheim is Gilboa which is the middle one of the three southern townships of Schoharie co. The central part is crossed from the south to the north by the Schoharie river to the east of which, from a short distance below Gilboa village to beyond the northern boundary of Gilboa and Blenheim townships, a high and precipitous hill rises. The two other principal streams of the township are the Minekill, which rises in the eastern part of Jefferson township and enters the Schoharie river from the west, and the Plattenkill from the east.

XXVIII Z[1]. About half way between the villages of North Blenheim and Gilboa is the Minekill the lower part of its course running very near the township line. Just to the south of the Minekill along the western bank of the Schoharie river are bluish shales in which a few imperfectly preserved fossils occur. The rocks however are principally rather thin, bluish sandstones, apparently unfossiliferous and there is one prominent layer of green shales. The fossils from the blue shales near the mouth of a brook south of the Minekill are so imperfectly preserved and fragmentary that it is scarcely possible to identify them more than generically. The list as far as the specimens were determined is as follows:

1 *Liorhynchus* (?) or
Camarotoechia (?) sp. (c)
The specimens do not seem to agree closely with the figures of the Ithaca species of either of the above genera.

2 (?) *Palaeoneilo* sp. (rr)
Broken specimen showing the characters imperfectly.

3 *Orbiculoidea neglecta* Hall (?) (rr)
Specimen imperfectly preserved but apparently this species.

4 Lamellibranch (rr)
Fragment of long shell in which the *Discina* is imbedded.

In the Minekill just below the main river road are the cascade and gorge known as the Minekill falls. The gorge at the cascade is very narrow and the walls are perpendicular, perhaps 100 feet high. The main part of it is cut out of a sparingly fossilifer-

ous blue shale which contains an occasional thin layer of sandstone. There are also thin layers of small, iron stained concretions and at the lower end of the gorge are some greenish shales. It is probable that these rocks are in the Ithaca formation although the list of fossils given below does not furnish very conclusive evidence for *Spirifer mesastrialis* Hall was not found.

1 *Tropidoleptus carinatus* (Con.) Hall	(c)
2 *Spirifer mucronatus* (Con.) Bill.	(c)
3 *Chonetes setigera* Hall	(c)
4 *Orthothetes chemungensis* (Con.) H. & C. (?)	(rr)
5 *Nuculites oblongatus* Con.	(rr)
6 *Leda brevirostris* Hall	(rr)
7 *Lunulicardium fragile* Hall	(rr)

At the brink of the upper cascade and on the banks of the creek above is a blue, fairly massive sandstone containing *Psilophyton princeps* Dn. and other plant stems.

XXVIII Z². By the side of the road toward West Gilboa and about west of the Minekill falls are fine blue shales which are 365 feet or more above the level of the Schoharie river and below them are some quite heavy sandstones. The shales are fairly fossiliferous and are in the Ithaca formation. The following species were collected in a few moments:

1 *Nuculites oblongatus* Con. (?) Posterior part missing.	(rr)
2 *Tropidoleptus carinatus* (Con.) Hall	(rr)
3 *Spirifer tullius* Hall	(c)
4 *S. mesastrialis* Hall (?) Poorly preserved.	(r)
5 Lamellibranch shell. Imperfectly preserved.	

XXVIII Z³. On the Minekill four miles west of the Schoharie river is the little hamlet of West Gilboa or Shoe Hollow. The rocks along the highway from Z² to this place are well covered, with only now and then an outcrop of a sandstone stratum or a little shale. On the hill one fourth mile north of West Gilboa are greenish shales in which *Spirifer mesastrialis* Hall is abundant. The following species were obtained:

1 *Spirifer mucronatus* (Con.) Bill. (rr)
2 *S. mesastrialis* Hall (a)
Thin layers nearly filled with these shells.
3 *Tropidoleptus carinatus* (Con.) Hall (rr)
4 *Microdon (Cypricardella) gregarius* Hall (?) (rr)
Imperfectly preserved.
5 *Palaeoneilo constricta* (Con.) Hall (?) (rr)
Imperfectly preserved.

Only a few feet higher are ledges of thin red sandstone and mottled red and green shale (Z^4) approximately 590 feet above the level of the Schoharie river. To the north of this hill about one mile from West Gilboa is Pigeon creek, a tributary of the Minekill from the north. Along the highway on the northern bank of this creek as far as the first road are frequent pieces of sandstone containing fossils, frequently *Spirifer mesastrialis* Hall. These blocks were not found in place but it seems probable that they occur in place above the zone of reds described near West Gilboa. Higher on this hill forming the divide between the Minekill and Mill creek are large numbers of loose, angular, blocks of red sandstone. This seems to show that a considerable amount of the red occurs in this hill interstratified with the coarse grained, grayish to greenish gray sandstone. Mixed, loose specimens of these two colored sandstones occur well toward Ruth church which is on the high part of the divide in the southwestern part of Blenheim, 475 feet by the barometer above the red sandstone north of West Gilboa. Not far from Ruth are large quantities of loose, angular blocks of greenish gray sandstone similar to the typical Oneonta. Loose by the highway about one fourth mile west of West Gilboa are blocks of greenish sandstone containing Ithaca fossils some of them having large numbers of *Spirifers*. It is not clear whether these blocks came from a horizon below or above the red sandstone of Z^4, but the following species were collected from them:

1 *Spirifer mesastrialis* Hall (rr)
Two broken shells.
2 *S. mucronatus* (Con.) Bill. (?) (rr)
Two fragments and one small specimen.

3 *Microdon (Cypricardella) gregarius* Hall (rr)

4 *Nuculites cuneiformis* Con. (?) (rr)

Shell imperfectly preserved.

5 *Palaeoneilo* sp. (r)

Heavy concentric markings like *P. emarginata* (Con.) Hall; but there is no constriction. Something like the shells found in the Ithaca in N. E. Pennsylvania.

Not far west of West Gilboa loose blocks of red sandstone occur frequently along the highway, but a ledge was not seen in place. In fact there are but comparatively few exposures of rocks in place along the upper course of the Minekill. Some two and one half miles above West Gilboa loose blocks containing fossils were seen by the highway, but it is not certain that they came from that immediate vicinity. In these blocks the following species were obtained:

1 *Spirifer mesastrialis* Hall (rr)

2 *Homalonotus dekayi* (Green) Emm. (?) (rr)

3 *Paleoneilo emarginata* (Con.) Hall var. (c)

The posterior emargination, as in Pennsylvania specimens, is not as deep as on typical specimens of this species.

4 *Microdon (Cypricardella)* sp.

Too imperfect for specific identification.

LXXV E[1]. On the western bank of the Schoharie nearly two miles below Gilboa where the road runs very near the river are massive unfossiliferous sandstones which are fairly coarse grained and mostly gray in color with but a faint tint of green. Perhaps one fourth mile below the Gilboa bridge near the bank of the river is a small quarry E[2] which has been worked to some extent for building stone. The rock is a massive, rather coarse grained, greenish gray sandstone which runs down to river level, some 20 feet being exposed. No fossils were found in the bed rock; but on the stone wall along the highway at this locality are large blocks of bluish sandstone containing specimens of *Tropidoleptus carinatus* (Con.) Hall; *Spirifer* sp.; *Glyptodesma erectum* (Con.) Hall and other fossils. Careful search was made for this zone in the vicinity of Gilboa but without success and it is probable that the specimens came from the drift. Along the highway from

E^1 to Gilboa the soil is frequently quite reddish indicating the nearness of red rocks. Above and below the highway bridge over the Schoharie river at Gilboa is a rocky gorge (E^3) with walls of shales and sandstones. The sandstones in general are coarse grained and somewhat greenish gray in color, the greenish tint being much stronger than in the sandstone of E^1, and alternating with them are shales usually greenish in color though some of them are blue. The blue shales contain fragments of *Rhodea pinnata* Dn. A specimen was submitted to Prof. D. P. Penhallow who kindly compared it with the types in the museum of McGill university and wrote, it " is undoubtedly to be referred to *Rhodea pinnata* as a comparison with our types clearly shows." In some of the blocky, greenish shale by the roadside below the bridge are fish scales. From the bridge for several rods up the stream along the bank not much above the water is a stratum of brownish red, silicious sandstone, nine inches in thickness. The lower part of the stratum is of a reddish green color On the bank above the highway just south of the bridge is a stratum of heavy, coarse grained, gray sandstone which contained the trunks of the tree ferns, *Psaronius textilis* Dn., which were exposed by the freshet of September 1869. Several of the trunks were secured by Prof. Hall and are now in the state museum of natural history. Prof. Hall described at an early date[a] the circumstances attending their discovery and submitted them to Sir William Dawson for description.[b] The impression of the side of one of these trunks still shows very clearly in the sandstone at this locality.

LXXV B^1. On the eastern bank of the Schoharie one mile below Gilboa is a steep cliff rising very abruptly from the river. The rocks consist of massive greenish sandstones alternating with greenish and blue argillaceous shales. The dip is from 1° to 1½° S 50° E. In the river near the bank are large blocks of greenish sandstone, similar to the stone in the quarry on the western bank farther up the stream. On one of the largest blocks which did not appear to have been transported far by the

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a 24th an. rep't N. Y. state museum of nat. history, 1872, p. 8, 15-16.

b Quarterly jour. geol. society—London, 1871, 27:269; and Geol. surv. Canada, the fossil plants of the Devonian and Upper Silurian formations of Canada, 1871, p. 59.

Plate 11

river, are a number of good specimens of *Amnigenia catskillensis* (Van.) Hall, the characteristic fossil of the Oneonta sandstone.

LXXV F. One mile above Gilboa the Manorkill enters the Schoharie river from the east. Only a short distance from its mouth are the Manorkill falls, or cascade, which occur in a pretty glen that is quite a popular resort for picnic parties during the summer. The accompanying picture gives a fairly good idea of the falls. Below them reaching to the level of the Schoharie river is massive greenish gray sandstone with the lithological appearance of the Oneonta.

According to Sherwood's section[a] the base of the cascade is 57 feet above the top of the sandstone which contains the tree ferns, *Psaronius textilis* Dn., at Gilboa. Above the bridge there is a small fall above which on the southern bank of the creek are bluish to greenish crumbly shales containing fish plates one of which was recognized by Dr Eastman as probably belonging to *Bothriolepis minor* Newb. The number of specimens is not great and the fossiliferous layer apparently does not have any considerable extent. A few feet above are red shales forming a well marked zone in the sides of the glen, 12 feet in thickness. The rocks have a thickness of 120 feet from the foot of the cascade to the base of this zone of red shale as measured by Sherwood. The dip in the glen above the bridge varies somewhat with different strata, but is decidedly to the southeast. On the northern bank it ranges from 1°–3½°; while on the southern bank a dip of 1½° almost directly east was noted. Several small specimens of *Psaronius textilis* Dn. were found by the side of the highway when this locality was first visited, which apparently came from some of the greenish gray sandstone when the excavations were made for the foundation of the bridge.

At the saw mill one quarter mile above the mouth of the Manorkill and 200 feet above the level of the Schoharie river are red sandstones and shales, 12 feet of which are exposed. Between the two zones of red shale there are some 56 feet of grayish sandstone and shale shown along the bank of the creek. This

a Proc. Amer. philosophical society, 17:347.

upper zone of red shale was supposed by Sherwood to be the same bed as the one of red and green shale in the Kaaterskill creek above the upper end of Palenville.[a]

On the *Geologic map of New York*, published in 1844, the top of the Chemung rocks was represented as crossing the Schoharie river at the mouth of the Manorkill, and the Chemung was succeeded by rocks then considered Catskill. The rocks in the vicinity of Gilboa, specially at the Manorkill were quite well described by Emmons who correlated them with coarse sandstone found near Mt Upton and now known as the Oneonta sandstone. The rocks at the Manorkill and vicinity succeeding those in the more immediate neighborhood of Gilboa were described as follows by Emmons, "An undefined mass of gray sandstone succeeds, which contains land vegetables, and, at the Manorkill falls, one mile above the village, also contains numerous fossils, among which are several *Cypricardia* two species of *Solen* and what appears to be the *Terebratula lepida*. The rocks are coarse grits at the falls, with some layers of green tough shale, in which are contained most of the *Cypricardia*. The tough, lumpy character of this shale is a great inconvenience to the collector of fossils. Above the Manorkill falls, the red marl or slate is many feet thick. This is succeeded by the greenish and coarse sandstone shales alternating for five or six hundred feet, and appearing in high and steep escarpments on the mountain half a mile north of the kill; the rock contains a few *Cypricardia*. The whole series is fossiliferous; more so, we think, than what appears upon a cursory examination, principally on account of the coarseness of the grits and the unfavorable state of the stratification. The beds at and immediately above the bank of the creek near the village are destitute of animal remains, or at least we did not succeed in finding any. Now the stratum which contains vegetables at other places contains also *Cypricardia*. In this stratum, many fragments of stems and long leaves are preserved, but crushed, and so broken that they are worthless as cabinet specimens, yet the stratum itself is a good guide for the rock. It is

a Proc. Amer. philosophical society, 17: 347.

Plate 12

Manorkill falls, Gilboa

the same as that described in Mr Vanuxem's report, in which he first discovered the fossils at Mt Upton on the Unadilla. The discovery of this stratum (or strata, for there are several) at Gilboa, at the base of adjacent mountains, identifies two distant series, and proves their equivalency and age. . . It has been said that the rocks of Gilboa belong to the Hamilton group, and as fossils closely resembling those of this formation were discovered six or seven hundred feet at least above the locality on the Manorkill, where Devonian fossils had been found, it became important to accumulate as many facts as possible which would bear upon the question; and we were fortunate enough to discover the remains of fish in the strata between Prattsville and Gilboa, and, what was still more satisfactory was their association with the *Cypricardia catskillensis* [*Amnigenia catskillensis* (Van.) Hall] discovered by Mr Vanuxem, on the Unadilla. These fossils will undoubtedly be found quite numerous in this neighborhood, as we observed several specimens in the rock two miles above Prattsville, on the banks of the creek. It appears, therefore, that it has a wide range in this series, and may be regarded as characteristic of the formation in which it is found."[a]

Darton states that the Oneonta formation "begins at the Manorkill falls and extends about 12 miles southward"[b]; while on the *Geologic map of New York* the red shales in the gorge above the highway are apparently considered as marking the bottom of the formation.

On the geological map accompanying this report the writer has accepted for the base of the Oneonta formation from the Schoharie valley eastward, the lowest thick beds of red shales and sandstones accompanied by coarse greenish gray sandstones. These red rocks are not considered as marking the same horizon from this valley eastward, for the evidence seems to the writer to clearly show that the reds appear at a lower horizon as they are followed into Albany and Greene counties. The lowest reds, however, seem to be about the only zone that can be followed for the purpose

a Agriculture of New York, 1846, 1:195-96.
b Amer. jour. science, 3d ser. 45:206.

of geological mapping and consequently that has been taken for the base of the Oneonta formation.

Along the Schoharie valley there is an alternation of the lithologic characters and faunas characterizing the Ithaca and Oneonta formations for several hundred feet. In the greenish sandstones at the Manorkill or along the Schoharie near Gilboa, *Amnigenia catskillensis* (Van.) Hall was not found in place; but specimens were found in large blocks of this sandstone along the bank of the river which probably came from these sandstones. Considerably higher above these red and greenish gray sandstones a meager Ithaca fauna was found at several places in the Schoharie and Manorkill valleys. It was not satisfactorily determined whether these highest fossiliferous layers occur at a higher stratigraphic position than the top of the Ithaca fauna in the Susquehanna valley, but it is clear that the lithologic conditions of the Oneonta formation appear at a lower stratigraphic position in the Schoharie than in the Susquehanna valley and that there is an alternation of these conditions through a thickness of several hundred feet of rocks. The Schoharie section is along the region of oscillation, between the marine waters with the Ithaca fauna of the west and the brackish waters of the east. In the Susquehanna valley during this time, marine waters prevailed as shown by the faunas, and there is no evidence of the brackish waters; while in Albany and Greene counties the brackish waters dominated and there is scarcely any evidence of marine faunas.

LXXV A^1. This section extends from the Schoharie river at the Gilboa bridge along the highway toward Grand Gorge for more than one mile, and then to the top of the hill about south of Gilboa. It is an especially interesting one since it shows the presence of a fauna with a considerable number of species, over 400 feet above the river level and the first stratum of red rocks at Gilboa. The lower part of the section (A^1) is pretty well covered, but there are some outcrops which give a general idea of the lithologic characters of the rocks. At the base are massive sandstones, above

Plate 13

MANORKILL FALLS ABOVE THE BRIDGE

the stratum of red rock in the river gorge, which are coarse grained and grayish or greenish gray; then there are greenish shales followed by reddish sandstone. Higher are greenish and bluish shales and sandstones, and about 200 feet above the river level is the top of another zone of red shales.

LXXV A^{2-4}. By the side of the highway toward Grand Gorge near the southern line of Gilboa township, 375 feet above the Schoharie river at Gilboa, are grayish to greenish gray non-fossiliferous sandstones alternating for about 15 feet with thin layers in which fossils are very abundant. The most abundant species is *Spirifer mesastrialis* Hall, and these shells are so numerous that the layers form a sort of fire stone. These are succeeded by some 30 feet of greenish gray, thin bedded sandstones (A^3) at the surface which at a greater depth form massive layers that are somewhat irregularly bedded. The dip as measured by the ledges at the side of the road varies from a little less to more than 2° S, 50° W. There is an occasional fossil in these sandstones as well as some clay pebbles. Below a ledge of massive, irregularly bedded sandstone are bluish, rather thin, argillaceous shales. These rocks make a prominent ledge in appearance, not unlike certain sandstones in the Oneonta formation. At the top of these sandstones, 420 feet above the river at Gilboa is another fossiliferous zone, (A^4), having the lithologic appearance of the lower one and containing abundant specimens of *Spirifer mesastrialis* Hall. From zones A^2 and A^4 the following species were collected:

1 *Spirifer mucronatus* (Con.) Bill.	(r)
2 *S. mesastrialis* Hall	(aa)
Very abundant in these thin layers.	
3 *Camarotoechia eximia* Hall	(c)
4 *Tropidoleptus carinatus* (Con.) Hall	(a)
5 *Palaeoneilo emarginata* (Con.) Hall var.	(r)
6 *Microdon (Cypricardella) complanatus* Hall	(rr)
7 *M. (C.) gregarius* Hall	(rr)
8 *Actinopteria boydi* (Con.) Hall	(r)

9 *Pterinopecten* cf. *Vertumnus* Hall (rr)

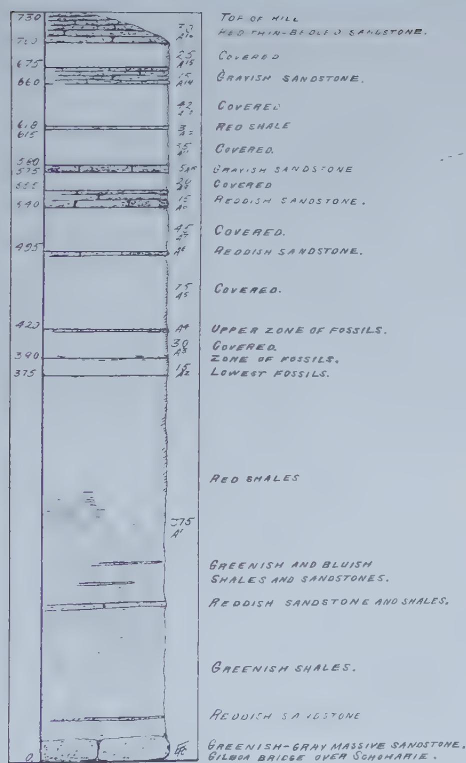
10 (?) *Nuculites* sp. (rr)

Large specimen in shape somewhat like *N. cuneiformis* (Con.) though considerably longer and showing concentric striae.

These fossiliferous layers are apparently in the same general stratigraphic position as the loose fossils found on the hill north of West Gilboa toward Ruth and in the hill northeast of Gilboa which will be described after this section. They are clearly above the zones of red shales shown in the gorge above the Manorkill falls and about 200 feet above the lower one. Succeeding zone A^4 for 310 feet to the top of the hill 730 feet above the base of the section the rocks are partly covered, but there are frequent exposures showing an alternation of grayish sandstones with red shales and sandstones. The thickness and alternation of these rocks are shown on the accompanying diagrammatic section and their lithological characters agree either with those of the Oneonta or Catskill formations. No fossils were found above A^4 except trails of worms on a loose specimen of grayish sandstone. The accompanying "Geological section along the Schoharie river from Schoharie to Gilboa" is intended to give an idea of the topographic outline of the hills to the west of the Schoharie river as well as the order and extent of the formations. On account of the lack of a topographic map of the Schoharie valley region it was difficult to represent this section with any great accuracy and it is to be regarded as a somewhat generalized section. It is thought, however, that it will give an impression of the rugged nature of this region and a somewhat graphic representation of the several formations which have already been described.

LXXV O^{1-2}. About one mile below Gilboa the Plattenkill or Flat creek enters the Schoharie river from the east. Between this creek and the Schoharie river is a high hill with a very steep bank toward the river. On the southern end of this hill to the west of the Plattenkill and one and one half miles northeast of Gilboa are greenish gray massive sandstones (O^1) while in shales

No. 75, A. SECTION OF S.W. OF GILBOA.



(O^2) above the sandstones are fossils, *Spirifer mesastrialis* Hall being abundant. This species is associated with some others and in the few minutes spent in hunting for fossils at this locality the following list was obtained:

1	*Spirifer mesastrialis* Hall	(a)
2	*Tropidoleptus carinatus* (Con.) Hall	(rr)
3	*Camarotoechia* sp. Too imperfectly preserved for specific identification.	(r)
4	*Goniophora* cf. *hamiltonensis* (Hall) Miller	(rr)
5	*Actinopteria boydi* (Con.) Hall	(rr)

In the massive sandstones below the fossiliferous shales *Amnigenia catskillensis* (Van.) Hall occurs, which is considered the characteristic fossil of the Oneonta sandstone. Below the massive sandstones on the hillside are numerous loose pieces of red shale and sandstone. This fossiliferous zone is some 600 feet above the Schoharie river at Gilboa and clearly above the lowest zones of red shale in that vicinity and at the Manorkill. The lithologic character and fauna of the massive, greenish gray sandstones (O^1) are those of the Oneonta formation, while the shales of O^2 contain an Ithaca fauna similar to that of zones A^2 and A^4 to the southwest of Gilboa. A dip of about 90 feet a mile to the southwest would carry the zone O^2 down to the horizon of A^2 which is between two and one half and three miles farther southwest.

LXXV X^2. An interesting section was studied farther northeast on the Mackey farm to the west of the Plattenkill. This locality is about two and three quarters miles northeast of Gilboa and the Plattenkill at that locality is some 550 feet higher than the Schoharie river at the mouth of the creek. On the Mackey farm 140 feet higher than the creek is a ledge of uneven bedded, grayish and rather coarse grained sandstones. 20 feet higher or approximately 710 feet above the Schoharie river are thin bedded, grayish sandstones (X^2) which contain quite a number of species, *Spirifer mesastrialis* Hall occurring abundantly. The fauna is as follows:

1	*Spirifer mesastrialis* Hall	(aa)
2	*S. mucronatus* (Con.) Bill. (?)	(rr)
3	*Tropidoleptus carinatus* (Con.) Hall	(rr)
4	*Camarotoechia stevensi* (Hall) H. & C. (?) Poorly preserved.	(c)
5	*Nucula corbuliformis* Hall	(rr)
6	*Leda diversa* Hall	(rr)
7	*Goniophora carinata* (Con.) Hall	(rr)
8	*Coleolus aciculum* Hall	(rr)
9	*Microdon (Cypricardella) complanatus* Hall	(rr)
10	*M. (C.) gregarius* Hall	(r)
11	*Actinopteria boydi* (Con.) Hall	(c)
12	*Pterinopecten suborbicularis* Hall (?)	(c)

It is to be noted that *Spirifer mesastrialis* Hall is abundant in the three faunas of LXXV $A^{2, 4}$, O^2 and X^2 and that the species of Brachiopoda are nearly the same in the three lists. X^2 is about one and one quarter miles northeast of O^2 and approximately 110 feet higher. It seems reasonably certain to the writer that these three zones are near the same horizon and that there is a general dip of about 90 feet a mile to the southwest across this part of the Schoharie valley. The observations of dip made on the cliff one mile below Gilboa and at the Manorkill falls do not agree with this conclusion and possibly the fossils occur at three different horizons, but the writer inclines to the former opinion. 65 feet above X^2 are thin, gray sandstones eight feet in thickness, but no fossils were found in this ledge. Then for 117 feet the rocks are concealed when another gray ledge of thin sandstones is reached at the top of the hill, approximately 900 feet above the Schoharie river level. The details of this section are shown in the following diagram.

SECTION ON THE WESTERN SIDE OF THE PLATTENKILL $2\frac{3}{4}$ MILES NORTHEAST OF GILBOA

LXXV X

900′		X³ Thin gray sandstones at top of hill
	117′	
	8′	Thin gray sandstone
775′		
	65′	
710′		X² Thin sandstones with fossils
	20′	
690′		Grayish sandstone
		X¹
	140′	
550′		Plattenkill at the Mackey farm
	550′	X¹
0′		Schoharie river level

Farther up the Plattenkill valley is an abundance of red shale and sandstone. At the corners three fifths of a mile south of

Mackey's Corners are reddish sandstones which are two and four tenths miles northeast of the Mackey farm and some 70 feet higher than the fossiliferous zone of X^2. Along the highway near the head of the Plattenkill, east of Mackey's Corners and the schoolhouse of district no. 18, are bright red shales and sandstones. This locality is one and two tenths miles northeast of the one just described and approximately 190 feet above the fossiliferous zone of X^2.

LXXV N. On the high plateau some two miles southeast of North Blenheim on the road turning south toward the Plattenkill from the old "state road" are conspicuous exposures of red shales (N^1) which are approximately 1160 feet higher than the Schoharie river at North Blenheim. About one half mile farther south by the side of this highway are loose, bluish sandstones (N^2) which weather to a slightly olive tint and judging from their angular form evidently came from that immediate vicinity. These sandstones are 115 feet above the red shales of N^1 or approximately 1275 feet higher than the Schoharie river at North Blenheim and about three miles north of the fossiliferous shales O^2 at the southern end of this hill. Fossils are quite common in them, specially *Spirifer mesastrialis* Hall and *Actinopteria boydi* (Con.) Hall. The complete list of species is as follows:

1 *Spirifer mesastrialis* Hall (a)
2 *Tropidoleptus carinatus* (Con.) Hall (r)
3 *Camarotoechia eximia* Hall (c)
4 *C. stevensi* Hall (?) (r)

Possibly *C. eximia* for these two species are very closely related.

5 *Goniophora hamiltonensis* (Hall) Miller (c)
6 *Actinopteria boydi* (Con.) Hall (c)
7 *Grammysia obsoleta* Hall (?) (rr)
8 *G. bisulcata* (Con.) Hall (rr)
9 *Sphenotus solenoides* Hall (?) (rr)

There are none of the vascular markings on the posterior part of the shell said to be characteristic of this species; but in other respects it agrees with it.

LXXV M. A section was roughly measured from the Schoharie river bridge below North Blenheim along the highway and brook up the steep hill on the eastern side of the river through Mackey's Corners to the top of Leonard hill in the eastern part of the township. The hill slope is well covered by drift so that the section is not as satisfactory as might be desired. For 440 feet up the hill the rocks are all concealed along the highway, when an exposure of bluish shales (M^2) occurs in which are a few poorly preserved fossils.

1 *Liorhynchus multicosta* Hall (?) (c)

The specimens are all quite small and resemble the "young individual," fig. 26, pl. 56, *Paleontology*, v. 4, more closely than any other.

2 *Coleolus tenuicinctum* Hall (?) (rr)

Just the point of apparently a specimen of the above species.

So few fossils were found in these shales that they assist very little in determining their age but judging from the sections on the western side of the river at North Blenheim it seems probable that they are not older than the Sherburne formation. 40 feet higher are coarse grained, thin gray sandstones (M^3) which contain more fossils both in number of specimens and species, as will be seen by following list:

1 *Spirifer mucronatus* (Con.) Bill. (c)
2 *Chonetes setigera* Hall (c)
3 *Tropidoleptus carinatus* (Con.) Hall (r)
4 *Leda diversa* Hall (rr)
5 *Orthonota undulata* Con. (rr)
6 *Schizodus appressus* (Con.) Hall (rr)
7 *Orbiculoidea* sp. (rr)

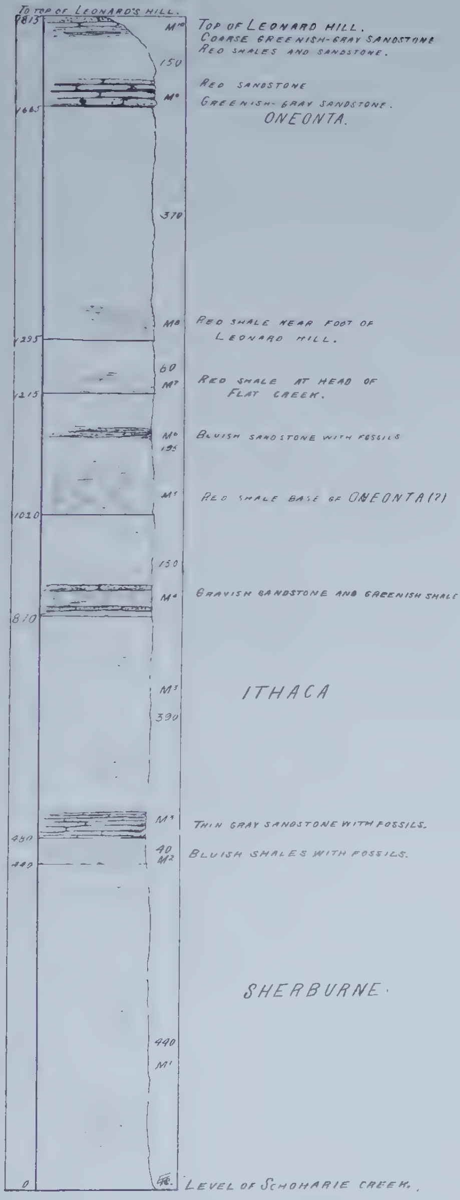
The species in this list are Hamilton and on account of their stratigraphic position they are not diagnostic. The outcrop is probably in the Ithaca formation and is something like 800 feet below the fossiliferous sandstones of LXXV N^2, on the hill to the southeast. Then for about 390 feet the rocks are mostly covered till in the upper part of the small brook thick bedded, coarse,

grayish sandstone occurs alternating with smooth, greenish shale (M^4). On the highway just east of the old "state road" at the Brown farm are red and greenish shales (M^5) at an elevation of 1020 feet above the river. The difference in altitude between these shales and the reds at LXXV N^1, on the hill to the southwest, is 140 feet, but the stratigraphic difference is much less on account of the southerly dip. These shales which are the first reds seen on this slope of the hill were regarded as marking the base of the Oneonta formation and are so represented on the map. One and one half miles to the northeast are the red shales of XXIX M^8 at 1250 feet above the river, and if XXIX M^8 and LXXV M^5 are in the same horizon then there is a dip of 150 feet a mile to the southwest.

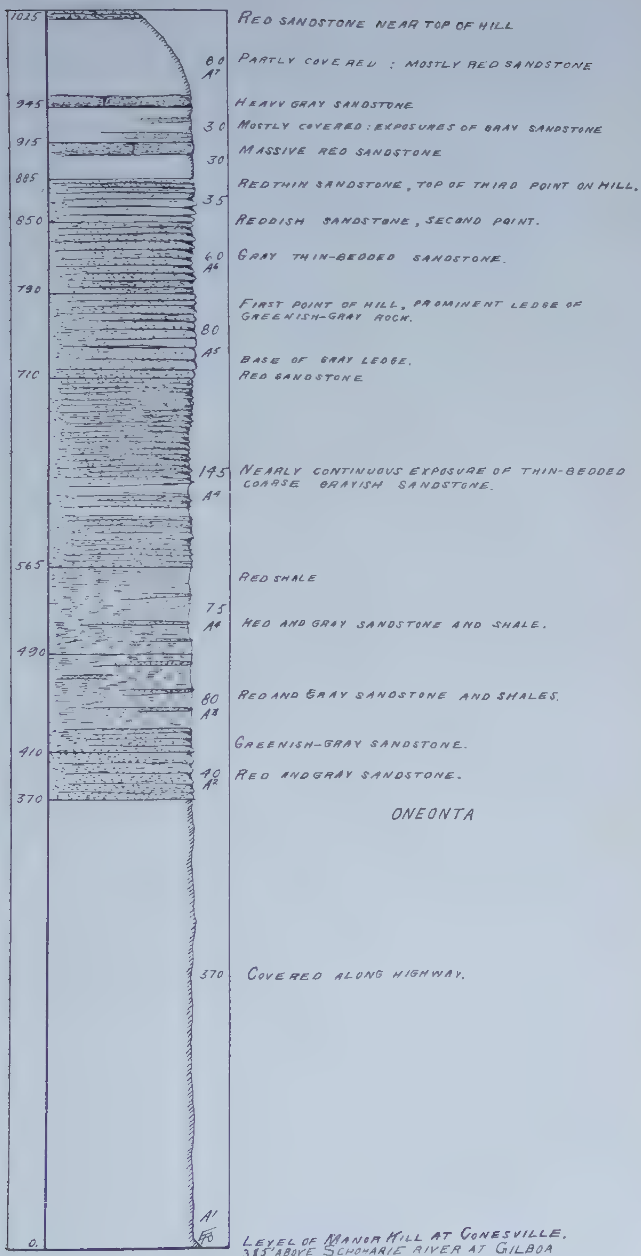
At the top of the divide three quarters of a mile west of Mackey's Corners are coarse grained, greenish sandstones associated with red ones. This locality is approximately 330 feet higher than the first reds at M^5, or some 1350 feet above the level of the Schoharie river. The country then descends to the east through Mackey's Corners to the head of the eastern fork of the Plattenkill or Flat creek at the foot of Leonard's hill. Plenty of bright red shales occur here (M^7) as well as along the highway toward Broome Center. According to the barometric readings these shales are 195 feet above the lowest reds at M^5 or 1215 feet above the Schoharie river; while from the creek to the top of the hill is 600 feet. This makes the top of Leonard hill at least 1815 feet above the Schoharie river at North Blenheim. The altitude of the North Blenheim bridge, according to Guyot, being 800 feet A. T. this section makes the top of Leonard hill 2615 feet A. T. The above section is a fairly accurate one for Guyot determined the elevation of Leonard hill by means of the mercurial barometer to be 2649 feet A. T.[a], which is only 34 feet more than that for the section just described. The slope of the hill is partly covered, but the exposures of rocks show an alternation of greenish gray, coarse grained sandstones with red shales and sandstones from

Amer. jour. science, 3d ser. 19:450. See p. 449 for elevation of North Blenheim.

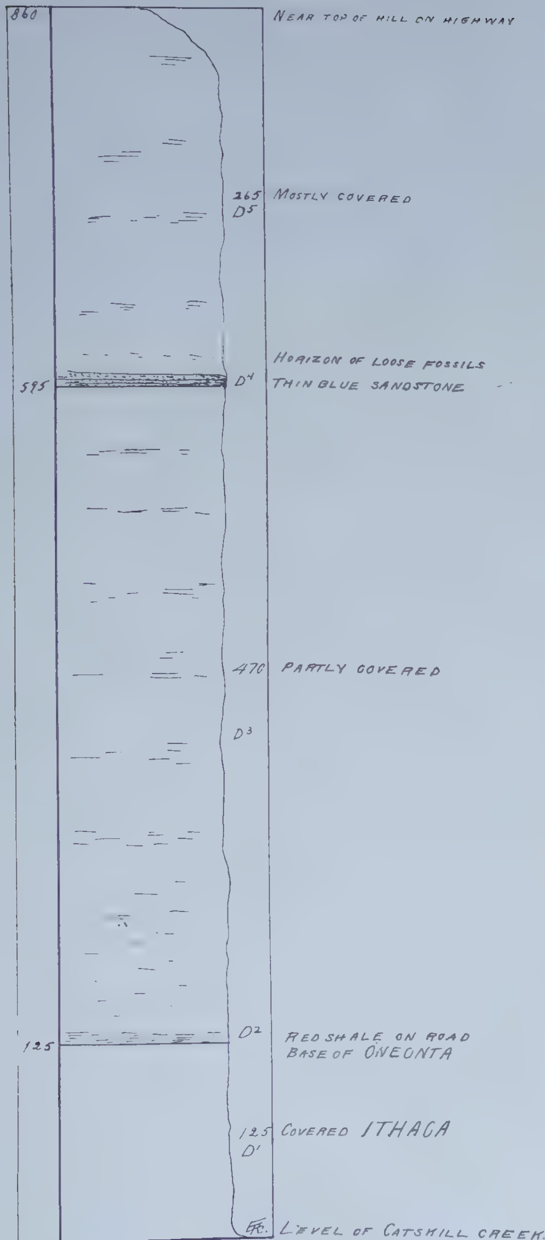
No. 75 M. SECTION
FROM
N. BLENHEIM



No. 61. A. SECTION
OF HILL SOUTH OF
CONESVILLE



No. 76, D. SECTION
SOUTHWEST OF
LIVINGSTONVILLE



the bottom to the top. The hill is capped by coarse, greenish gray sandstones, but only a little lower are red shales and sandstones. No fossils were found on the hill. The order of these various outcrops is shown in the reproduced section from the Schoharie river to the top of Leonard hill.

To the north of Leonard hill is Broome Center in the eastern part of Gilboa township with an elevation, according to Guyot, of 1973 feet A. T. On the highway about one quarter mile east of this village are ledges of coarse grained, greenish gray sandstones identical in lithologic characters with the typical Oneonta sandstone. On the hill across Keyser's creek, in the southwestern part of Broome township, between one and one half and two miles ENE of Broome Center are coarse gray sandstones on the road and in the field and perhaps 100 feet lower is a ledge of red rocks.

Conesville

To the south and east of Gilboa is Conesville, the southeastern township of Schoharie co. Its principal stream is the Manorkill, which rises in the Catskills in the eastern part of the township and flows westward emptying into the Schoharie river one mile above Gilboa. The eastern and northeastern portion of the township is crossed by the northern part of the northeast Border Chain of the Catskills, using Guyot's name, which terminates in Leonard hill, 2649 feet A. T., to the south of Broome Center in the southeastern part of Gilboa township. Along the southern border of the township to the south of the Manorkill is the Pisgah range, which descends very rapidly on the north into the Manorkill valley, and much more gently on the south in Greene county toward the valley of the Bataviakill.

LXXV W². The ledges on the hill to the north of the Manorkill, two miles above its mouth and about three miles from Gilboa, were examined somewhat carefully. This locality is about one mile below Conesville, formerly called Stone Bridge, from a highway bridge of stone over the Borerkill at that place. The creek highway is some 345 feet higher than the red sandstone in the

Schoharie gorge at Gilboa, and on the hillside 155 feet above the road or approximately 500 feet above the Schoharie at Gilboa, are ledges of thin, bluish gray sandstone. These sandstones contain a few fossils. One block of slightly greenish gray color was found which contained *Spirifer mesastrialis* Hall in abundance, but the other species occur rarely:

1 *Spirifer mesastrialis* Hall	(c)
2 *S. mucronatus* (Con.) Bill.	(rr)
3 *Tropidoleptus carinatus* (Con.) Hall	(r)
4 *Actinopteria boydi* (Con.) Hall (?)	(rr)
5 Lamellibranch undetermined	(rr)

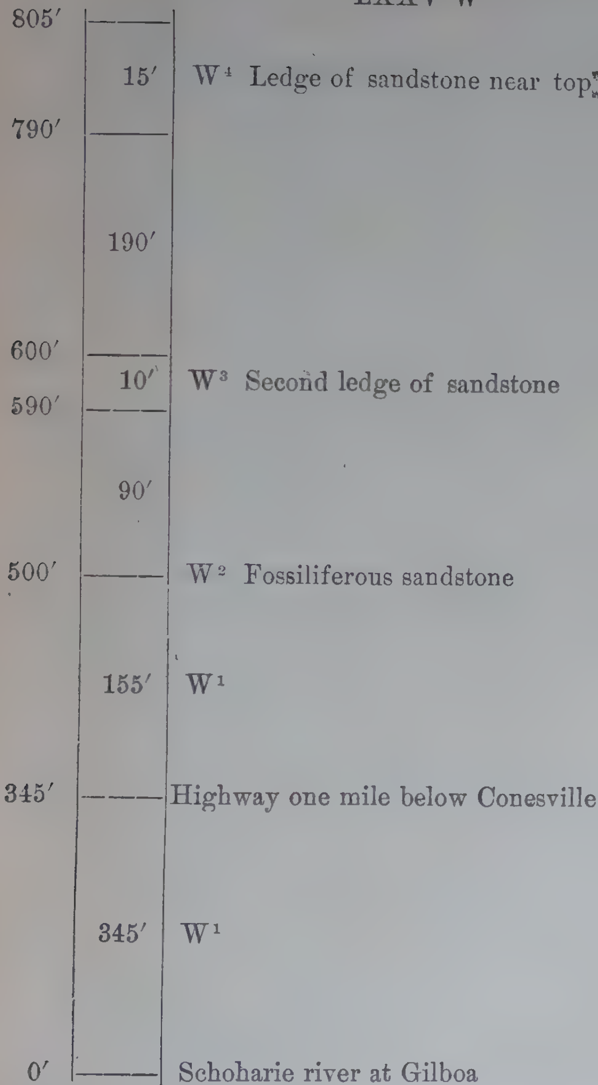
Two very imperfectly preserved species.

This fossiliferous zone is more than 200 feet above the zone of red sandstone occurring on the banks of the Manorkill (LXXV F), one fourth mile above its mouth, below Strykersville. That may not be the stratigraphic difference, however, for if the general dip is down the valley to the southwest then its position is lower in the vicinity of the Manorkill falls.

90 feet above the fossiliferous zone of W^2 is another ledge of thin bedded, bluish gray sandstone (W^3) 10 feet in thickness. No fossils were found in this ledge. Then for 190 feet the rocks are concealed when a heavy ledge of thin bedded, bluish gray sandstone (W^4) 15 feet thick occurs at the edge of the plateau which rises from this ledge very gradually toward the north. No fossils were found or red rock seen in place; but it is probable that formerly the plateau was capped by a reddish sandstone, for there are numerous flat and angular pieces of it scattered over the surface. As far as the outcrops are concerned there are no layers of red shale or sandstone in this slope, but it is quite probable that such layers occur though concealed by the drift. The following diagram represents graphically the above section:

SECTION ON THE NORTHERN SIDE OF THE MANORKILL, ONE MILE BELOW CONESVILLE

LXXV W



LXXV Y³. Conesville or Stone Bridge is approximately 395 feet above the red sandstone in the gorge of the Schoharie river at Gilboa, or according to Guyot 1382 feet A. T. To the northeast of the hamlet is a hill which, within less than a mile, rises fully

300 feet higher. Near the foot of this hill loose flat slabs of blue, rather fine grained sandstone were found in which fossils are common. It is not probable that these slabs came from ledges in the vicinity of Conesville since nothing similar to them was found in place in that region. It is, however, perhaps worth recording that two loose slabs with a similar fauna were noticed in the gorge of the Schoharie river below Gilboa. The loose blocks back of Conesville contained the following species:

1 *Spirifer* sp. (c)

Specimens badly broken and imperfectly preserved.

2 *Tropidoleptus carinatus* (Con.) Hall (rr)

3 *Glyptodesma erectum* (Con.) Hall (c)

4 *Grammysia bisulcata* (Con.) Hall (c)

5 *Bellerophon patulus* Hall (c)

At the brow of the hill about three fourths of a mile northeast of Conesville is a ledge of gray massive sandstones (Y^3) 45 feet in hight, known locally as "The Rocks," and fairly well shown in the accompanying plate. The base of the ledge is 225 feet above Conesville and approximately 620 feet above the Schoharie river at Gilboa. Some of the sandstone is thin bedded, while other layers are quite massive and there is frequently somewhat irregular structure. Some of the bluish gray sandstone which is quite coarse grained contains a few poorly preserved fossils, among which *Spirifer mesastrialis* Hall is the most common. A careful search furnished the following species:

1 *Spirifer mesastrialis* Hall (r)

Poorly preserved.

2 *Tropidoleptus carinatus* (Con.) Bill. (r)

3 *Pectinidae* (rr)

Too imperfectly preserved for generic identification.

4 (?) *Actinopteria* sp. (r)

Small and very imperfectly preserved specimens.

5 (?) *Spathella* cf. *typica* Hall (rr)

Larger than the figures of this species but in outline resembles it more closely than any of the other figures.

6 *Lepidodendron* sp. (rr)

7 Plant stems

Plate 14

“The Rocks,” Conesville. Oneonta

The fossils of Y^3 in actual altitude are about 120 feet above those of W^2 one mile farther down the Manorkill, but a southwesterly dip would reduce the amount of stratigraphic difference.

The stratigraphic position of these fossiliferous zones along the Manorkill were not determined to the satisfaction of the writer and he hopes to study that region more carefully in the near future. The following diagram explains the Conesville section:

SECTION NORTHEAST OF CONESVILLE

LXXV Y

665′		
	45′	Y^3 "The Rocks." Grayish sandstones containing a few fossils
620′		
	225′	Y^2 Covered
395′		Conesville
	395′	Y^1
0′		Schoharie river at Gilboa

The valley of the Manorkill not far above Conesville is crossed by quite a conspicuous moraine. Possibly a mile up the valley on its northern side and about 240 feet higher than Conesville is a 20 foot ledge of greenish gray, coarse grained, somewhat cross-bedded sandstone containing some white quartz pebbles. By the side of the highway not far below Manorkill village is a noticeable outcrop of red shale. From Manorkill with an altitude of 1520 feet A. T. there is a rise of 715 feet to the Sutton hill pass through the Catskills in the eastern part of this town-

ship, while Sutton hill is 2573 feet A. T. or 338 feet above the highway pass. On the western side of the mountains about 135 feet below the highway pass is a conspicuous ledge of coarse grained, crossbedded, bluish gray sandstone. At the edge of the outcrop are massive blocks which have separated from the solid stratum along the line of joints. No fossils were found except plant stems. 75 feet higher is the top of another heavy ledge of gray sandstone with red shale between the two sandstones. The upper gray sandstone is succeeded by red sandstone which is followed by red shales to the pass. Higher on the flanks of both Sutton hill and the one to the south of the pass are plenty of red shales and sandstones with some greenish sandstone, but these will be described later in the section from the Catskill creek on the east to the summit of this range. On the *Geologic map of New York* the red shales of Sutton pass are mapped as at the base of the Catskill formation, while the massive grayish to bluish gray sandstones below are called Chemung.

LXI A. To the south of the Manorkill along the southern border of the township is the steep Pisgah range which was examined along the highway crossing the range to the south of Conesville. It was determined that Conesville was about 395 feet above the stratum of red sandstone in the gorge of the Schoharie river and the Manorkill at this place is about 10 feet lower. A section was examined from the creek level along the highway to its summit and then to the crest of the range to the east of the highway. This section is shown on the plate so that it is only necessary to refer to its general details in this description. The lower 370 feet are concealed but red and gray sandstones are reached at the turn in the highway by the farmhouse. The alternation of red and gray sandstones and red shales continues to near the road summit, 565 feet above the level of the Manorkill. Then there are shown in the field to the east of the road about 145 feet of mainly thin bedded, coarse, grayish sandstone. Succeeding these gray to greenish gray sandstones predominate although there are some red layers for 140 feet to 850 feet above the Manorkill when

red sandstones apparently become more abundant and continue so nearly to the top of the range 1025 feet above the Manorkill. No fossils were found in the rocks of this section. From the top of this hill there is a fine view to the northeast of the eastern "Border Chain" of the Catskills from Sutton hill pass to Leonard hill; to the west are the high hills of the Schoharie river toward Summit and on the south and southeast is the Blackhead range.

On the *Geologic map of New York* the elevated part of this range to the east of the highway is mapped as in the Chemung. Its base is represented as considerably above the level of the road while the rocks on the western side of the road to the Schoharie valley and below along the Manorkill valley are mapped as Oneonta. Apparently the rocks mapped as Chemung are those shown in the upper part of section LXI A, which are composed to a considerable extent of reddish sandstones, perhaps one half of them having this color. The lithologic appearance of the rocks is not that of the Chemung and with no fossils to assist in determining it is difficult to see why they should be called Chemung. On the *Geologic map of New York* the Chemung formation capped by the Catskill is represented as following the northeast "Border Chain" of the Catskills from Sutton hill to near the northern line of the township. In this range to the northeast of Conesville is a conspicuous hill known as High Knob which is, according to Guyot, 2654 feet A. T. Its western slope is pretty well covered by soil but there are several prominent ledges which are indicated on the following section. Some 835 feet higher than Conesville near the foot of High Knob there is a coarse gray, irregularly bedded sandstone. 240 feet higher there is another heavy ledge of the coarse gray sandstone with some red sandstone below and reddish sandstone at its top. Near the top of the hill, 145 feet higher, is a heavy ledge of red sandstone below which is red shale; while the top of the ledge changes into a grayish sandstone.

SECTION OF HIGH KNOB

Elevation	Interval	Description
1255′		Top of High Knob
	35′	
1220′		Red sandstone with red shale below
	145′	
1075′		Reddish sandstone on top Third gray sandstone with red sandstone below
	100′	
975′		Second ledge of gray sandstone
	140′	
835′		Coarse gray ss near base of High Knob
	835′	
		Conesville, 390 feet above red stratum at Gilboa

It is thought that the elevations of the above section are fairly accurate since Conesville is 1382 feet A. T., which makes the elevation of High Knob 2637 feet A. T., only 17 feet less than that determined by Guyot. As far as the rocks are exposed, the greater part of High Knob seems to be composed of coarse, gray sandstones alternating with shales except toward the top where reddish sandstones and shales occur. One of the ledges of gray sandstone near the road to the southeast of High Knob has a dip of nearly 1° to the east of south. No fossils were found in the

rocks of High Knob or the other exposures along this chain of the Catskills and there is little evidence in favor of calling part of the section Chemung.

Broome

This township forms one of the eastern tier of Schoharie co. and is situated north of Conesville, east of Gilboa and Fulton and south of Middleburg townships. Catskill creek which rises in its northwestern part and thence flows southeasterly across it has in the eastern part of the township a narrow valley which is limited by high hills that rise very abruptly from it, specially the one on the southern bank to the south of Livingstonville. The township is noticeably a part of the high plateau of Albany and Schoharie counties deeply trenched by its streams. In the southern part is the deep valley of the upper part of Potter hollow creek; on the western side is the upper valley of Keyser's creek; across the central part is Catskill creek with the valley of Lake brook to the northeast; while the northeastern part slopes abruptly into the valley of Stony creek. In the northern part to the north of Franklinton is a marshy tract known as the "vly" forming the divide between the Catskill creek and a branch of Stony creek.

XXIX C[1]. On the hill west of the " vly " and one and one half miles NNW of Franklinton are ledges of grayish sandstone. Not far above the highway are heavy, somewhat reddish sandstones which in places have a mottled appearance. These exposures are not far east of those which have already been described in section XXXVII D on the eastern side of Moheganter hill. In quite large blocks loose on the surface are numerous specimens of very mucronate forms of *Spirifer mucronatus* (Con.) Bill., while in loose, thin sandstones the following species were found:

1	*Spirifer mucronatus* (Con.) Bill.	(aa)
2	*Camarotoechia congregata* (Con.) H. & C.	(c)
3	*Tentaculites attenuatus* Hall	(c)
4	*Goniophora hamiltonensis* (Hall) Miller	(rr)
5	*Glyptodesma erectum* (Con.) Hall	(rr)

These blocks seem to be from the Hamilton, but the rocks in place are apparently in the Sherburne or Ithaca formation. At the top of this hill is an outcrop of red sandstone which is placed in the Oneonta formation. This sandstone is about 600 feet above Franklinton, or as this village, according to Guyot is 1260 feet A. T., approximately 1860 feet A. T. This elevation is about the same as that of the lowest red sandstone, 1875 feet A. T., in section XXXVII C on the western side of Moheganter hill perhaps two miles farther west.

XXIX C². At the falls above the highway in the small brook a short distance northwest of Franklinton are fossiliferous bluish shales and thick, blue sandstone about 50 feet above the Catskill creek at Franklinton. The following species were collected at this locality:

1 *Spirifer mucronatus* (Con.) Bill. (a)
2 *S. granulosus* (Con.) H. & C. (?) (c)
Internal impressions probably of this species.
3 *S. mesastrialis* Hall (rr)
The two specimens of *Sp. mesastrialis* are on two pieces of rock, but I am not positive that they came from this locality. They may have been introduced accidentally. If they occur here, however, it would seem to indicate that I am in error in referring these rocks to the Hamilton.
4 *Camarotocchia congregata* (Con.) H. & C. (c)
5 *C. prolifica* Hall (?) (rr)
6 *Chonetes coronata* (Con.) Hall (c)
7 *C. setigera* Hall (r)
8 *Orthothetes chemungensis* (Con.) H. & C. var. *arctostriata* Hall (c)
9 *Paleoneilo constricta* (Con.) Hall
10 *Nyassa arguta* Hall (rr)
11 *Goniophora hamiltonensis* (Hall) Miller (rr)
12 *Grammysia* sp. (rr)
13 *Orthonota* (?) *parvula* Hall (rr)

14 *Actinopteria boydi* (Con.) Hall (c)

15 *Glyptodesma erectum* (Con.) Hall (r)

In sandstone.

16 *Tentaculites bellulus* Hall (?) (rr)

The above fauna is a Hamilton one which together with the lithologic appearance of the rocks seems to be sufficient evidence for referring the outcrop to the Hamilton formation. The top of the Hamilton passes beneath the level of the Catskill valley a mile or so below Franklinton. Along the highway north of Franklinton on the eastern side of the " vly " is a fairly massive ledge of sandstone which is about 10 feet higher than the exposures of XXIX C^2 on the western side. It was not examined for fossils but from its stratigraphic position is evidently in the Hamilton formation.

XXIX D^1. Near the top of the high hill one and one half miles northeast of Franklinton is a ledge of heavy, coarse grained, greenish gray sandstone with red shales and sandstone above. This ledge crosses the first east road to the north of Franklinton 950 feet higher than the Catskill creek at that place, some 2200 feet A. T. This outcrop is about at the summit of the plateau for this region and, 20 feet higher at the four corners, a short distance to the east, is red sandstone along the road bed. The hillside from the creek road to these ledges near its summit is well concealed by drift so that it is impossible to accurately determine the line of separation between the different formations. These red and greenish gray sandstones and shales are in the Oneonta formation, but not at its base as indicated by the red sandstone to the northwest of Franklinton 350 feet lower, and shown by reddish shales 300 feet lower on the northern slope of the hill toward Huntersland. In descending this slope toward Huntersland in Stony creek in the southeastern part of Middleburg, red shale was found at several places lower than D^1. The rocks are well shown along this highway and consist mainly of bluish sandstone alternating with reddish shales and sandstones and greenish shales. At an approximate altitude of 1910 feet

A. T., 320 feet below the top of the hill are two ledges of heavy, bluish sandstone between which are red shales (D^2). This horizon is approximately 650 feet above Huntersland which according to the barometric reading has about the same altitude as Franklinton. These were the lowest red rocks seen on the road and they were taken for the base of the Oneonta formation. It is interesting to note the close agreement in altitude of the lowest red rocks observed on the western side of Moheganter hill and at other points eastward as far as the hill south of Huntersland; 1875 feet on the western slope of Moheganter hill, 1860 feet northwest of Franklinton, and 1910 feet south of Huntersland. 140 feet below the sandstone and red shale of D^2 is the Alexander Campbell flagging stone quarry (D^3), approximately 410 feet above Huntersland. 15 feet of blue flagging stone capped by shales is shown, which was formerly worked to quite an extent. No fossils were found, except in some bluish shales a little blocky in texture.

1 *Leda diversa* Hall (rr)
2 *Nucula bellistriata* (Con.) Hall (rr)
3 *Goniophora hamiltonensis* (Hall) Miller (rr)

Below the quarry the rocks are mostly concealed by soil and drift to the level of Stony creek at Huntersland.

LXXVI C. On the eastern side of the Catskill creek and only a few rods above the highway one mile below Franklinton is a small glen with falls, the rocks in which consist largely of greenish shales and gray sandstone with some blue shale, and two layers of red rocks. The lower layer is a crumbly, mottled, red and green shale in the face of the falls and the higher one a sandstone with gray sandstone above and below. A loose block in the brook contained a specimen of *Spirifer mesastrialis* Hall, and there are plenty of loose pieces of conglomerate.

SECTION OF LXXVI C, ONE MILE BELOW FRANKLINTON

385′		C^5
	135′	Mostly covered
250′		C^4 Red sandstone between gray sandstone
	65′	
185′		C^3 Mottled red and green shale
	50′	
135′		C^2 Greenish shale at foot of glen
	50′	C^1 Covered
85′		Highway across brook
	85′	C^1
0′		Level of Catskill creek, $\frac{2}{3}$ miles above Livingstonville

LXXVI D. This section begins at the level of Catskill creek two thirds of a mile above Livingstonville and follows the highway and "Cain gulf" to the top of the hill two and two thirds miles west of this village. On the highway 125 feet above the level of Catskill creek are the lowest red rocks seen in place (D^2) consisting of clear red argillaceous shales which are exposed for some little distance. These red shales on the eastern and western sides of Catskill creek at C^3 and D^2 are regarded as nearly synchronous with rocks of similar lithologic appearance which a few miles farther east form a continuous section of red, green and bluish shales and sandstones. In recent geological papers these rocks have been regarded as belonging in the Oneonta formation. It will

be seen that in the vicinity of Livingstonville to the east and west of Catskill creek there are remnants of the Ithaca fauna above these lowest red rocks, and that there is something of an alteration in the lithologic appearance characterizing the two formations where typically developed. For the purpose of mapping, however, it was decided to consider the lowest reds as forming the base of the Oneonta formation and it is so represented on the accompanying map.

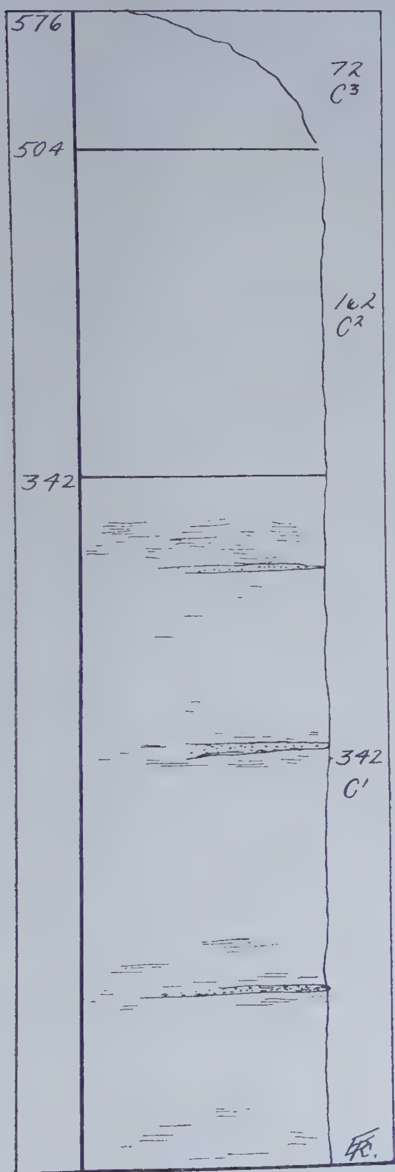
Above the red shales of D^2 the rocks are so well covered for 470 feet that no red rocks were seen and only an occasional ledge of heavy sandstone. Near the upper end of " Cain gulf " at the above altitude are thin, blue sandstones, (D^4), having a considerable thickness at this horizon, and in the field not far from this level a sort of cornstone was found in which there were a few, very poorly preserved fossils. The species are *Tropidoleptus carinatus* (Con.) Hall, and *Spirifer* cf. *mucronatus* (Con.) Bill., the latter being very imperfectly preserved, and perhaps they might be compared with *S. mesastrialis* Hall. The top of the hill is some 265 feet higher but the rocks are poorly exposed.

LXXVI E^1. One mile south of the upper part of section LXXVI D, is May's hill and the head of the southwestern fork of "Cain gulf" brook. Just below the east and west highway is a fall and the eastern bank opposite shows some 40 feet of grayish, blue, olive and red argillaceous shales and sandy layers to thin sandstones. Not much below the crest of the fall in a somewhat irregularly grained layer having red argillaceous shales above and below it a few fossils were found. Some of the fairly smooth greenish shales contain fragments of branching plants. The fossils are as follows:

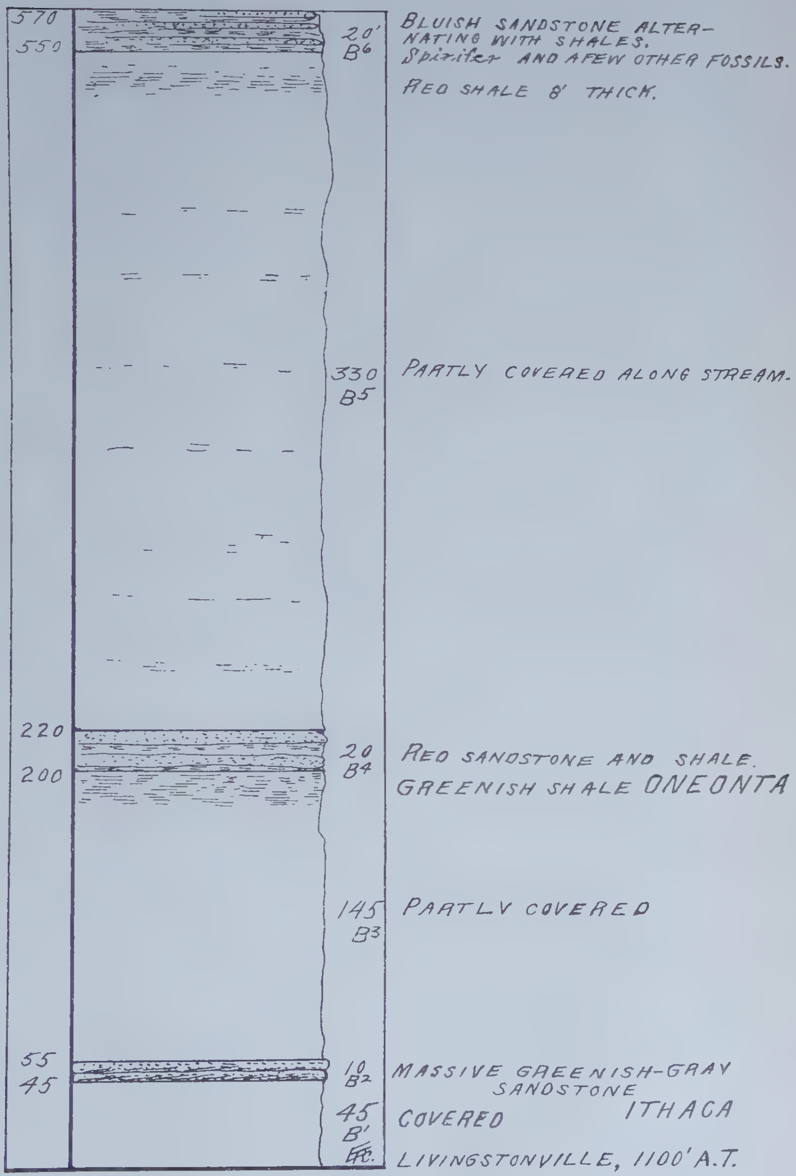
1	Brachiopod sp.	(c)
2	*Beyrichia* sp.	(r)
3	*Orthonota* sp.	(rr)

The above fossiliferous zone is 75 feet below the summit of the divide between Livingstonville and Smithton and in the neighborhood of 800 feet above Livingstonville.

No. 56, C. SECTION
NORTH OF
SMITHTON



No. 76, B. SECTION NORTH OF LIVINGSTONVILLE



The steep slope on the south side of the divide toward Smithton is well covered by drift and soil with occasional outcrops of sandstone and shales as shown in section LVI C. Smithton is over 500 feet higher than Cooksburg on the Catskill creek at the mouth of Potter hollow creek and on the road between Smithton and Potter hollow, 160 feet lower than Smithton, are plenty of red, argillaceous shales. It appears from the above statement that the steep hills to the north and south of Smithton are in the Oneonta formation.

LXXVI B. This section extends along Lake brook to the northeast of Livingstonville to Hoveyville and then up a branch about north of this hamlet. On the bank of Lake brook not far above Livingstonville and 45 feet higher is a ledge of massive, greenish gray sandstone (B^2) 10 feet in thickness. Loose in the brook, some threefourths of a mile above Livingstonville are pieces of blue shale in which are several specimens of a Lamellibranch similar to *Ptychopteria*. Another slab of coarse grained, greenish gray sandstone contains numerous worm trails and a fragment of *Spirifer* cf. *mesastrialis* Hall.

About one mile above Livingstonville and 200 feet higher or 1300 feet A. T. is an old mill in a rocky gorge (B^4). The lowest rocks in the bed of the brook are green shales and sandstones succeeded by 20 feet of red shales and sandstones; the shales forming the lower part of the red rocks which are capped by the red sandstone. This prominent ledge of red shale and sandstone is regarded as at the base of, or at least nearly so, the red rocks and is mapped as at the base of the Oneonta sandstone.

Along Lake brook and the "gulf" north of Hoveyville the rocks are partly covered with few exposures of the reds. In the "gulf" hardly three miles northeast of Livingstonville and approximately 330 feet higher than the red sandstone of B^4 are red, argillaceous shales, 8 feet thick, by the side of the road, and a little higher on the bank of the brook a ledge of bluish gray, rather coarse grained sandstone (B^6) which has thin, and somewhat irregular layers. The sandstone on the partings or where it is somewhat shaly contains some fossils, *Spirifer* occur-

ring in some abundance. This zone furnished the following species:

1 *Spirifer* cf. *mesastrialis* Hall (a)
2 *Goniophora carinata* (Con.) Hall (r)
3 *Palaeoneilo constricta* (Con.) Hall (rr)
4 *Actinopteria* sp. (rr)
Small and imperfect specimen.

A little higher is the main quarry of bluish sandstone alternating with shales in which from 15 to 20 feet of rocks are exposed. These rocks are also sparingly fossiliferous and the following species were obtained:

1 *Spirifer mucronatus* (Con.) Bill. (?) (rr)
2 *S.* cf. *mesastrialis* Hall (c)
There is but a very faint indication of the fine striae and possibly there are none.
3 *Sphenotus* cf. *truncatus* (Con.) Hall (rr)
4 *Palaeoneilo constricta* (Con.) Hall (rr)
5 *Palaeoneilo* sp. (rr)
6 *Leptodesma rogersi* Hall (rr)
7 *Sphenotus cuneatus* (Con.) Hall (?) (rr)
Broken and imperfectly preserved.
8 *Solen* (*Palaeosolen*) *siliquoideus* Hall (?) (rr)
Only the posterior half of the shell preserved.
9 *Modiomorpha subalata* (Con.) Hall var. *chemungensis* Hall (rr)
10 *Goniophora hamiltonensis* (Hall) Miller (rr)
11 *G.* *carinata* (Con.) Hall (rr)

A little farther up the "gulf road" the gorge becomes quite narrow at a place known as the "Devil's oven" and here is plenty of red shale (B^7) about 80 feet above the quarry sandstone. The altitude of this zone is 1750 feet A. T.; but the thickness of the rocks as given in the above section is too great on account of the heavy southerly dip. The fossils found here are a remnant of the Ithaca fauna, persisting after the conditions had changed mainly to those of the Oneonta formation. It is one of the last localities in following the strike of these formations to the eastward where

fossil mollusca have been found after the appearance of the red rocks in any considerable thickness.

The divide to the north between Lake and Stony brooks is some 375 feet higher than the red shales of B^7, or approximately 2125 feet A. T. On the northern slope in the southwestern corner of Berne township descending into the valley of Stony creek above Huntersland the lowest reds seen have an approximate altitude of 1870 feet A. T. If this be the lowest zone of the reds on this hill and LXXVI B^4 the same zone in Lake brook then it shows a dip of 142 feet a mile SSW. If a similar calculation be made between the zone of red shale in the southwestern corner of Berne township and the red shales of LXXVI D^2 on the hill west of Livingstonville there will be a dip of 120 feet a mile to the SW.

On the map accompanying this report the line of division between the Hamilton and Sherburne formations is represented as entering the northwestern part of Broome township; following the western side of the Catskill valley to a mile below Franklinton where it crosses the creek and then continues northerly along the side of the steep hills on the eastern side of the valley to the Broome-Middleburg township line when the trend is nearly easterly into the southwestern part of Berne township, Albany co.

For convenience in mapping, as has been stated, the lowest conspicuous zone of red rocks is considered as indicating the base of the Oneonta formation. This zone enters the northwestern corner of the township from Moheganter hill and follows the flank of the hill west of Catskill creek to near the Broome-Rensselaerville township line, where it crosses the creek and then running northerly to the northern slope of the high divide in the northern part of the township it turns east into the southwestern corner of Berne township.

ALBANY COUNTY

Albany co. lies to the east of Schoharie co. the southwestern third forming a part of the Helderberg plateau while the remainder of the county is a plain whose surface is somewhat

broken by low hills that extend on the north to the Mohawk river and on the east to the Hudson. The physiography and stratigraphy of this county have recently been quite fully described by Mr N. H. Darton in his paper entitled a "Preliminary report on the geology of Albany county."[a] The formations of the Middle and Upper Devonian occur only on the Helderberg plateau in the southwestern part of the county. On the eastern slope of the Catskills in the southwestern corner of the county are the latest rocks, probably of Catskill age, while the greater part of the three southwestern townships of Rensselaerville, Westerlo and Berne are covered by rocks belonging in the Oneonta, Sherburne and Hamilton formations. To the north and east of these townships is the Helderberg escarpment, which slopes very steeply toward the plain. It enters Knox township from Schoharie co. with a nearly east and west trend until it reaches Guilderland township when its direction changes to the southeast across the southern part of the county. The lower part of the escarpment is composed generally of several hundred feet of Hudson shales and sandstones of the Lower Silurian, while in its highest part on the eastern side the crest is in the lower half of the Hamilton formation.

Berne

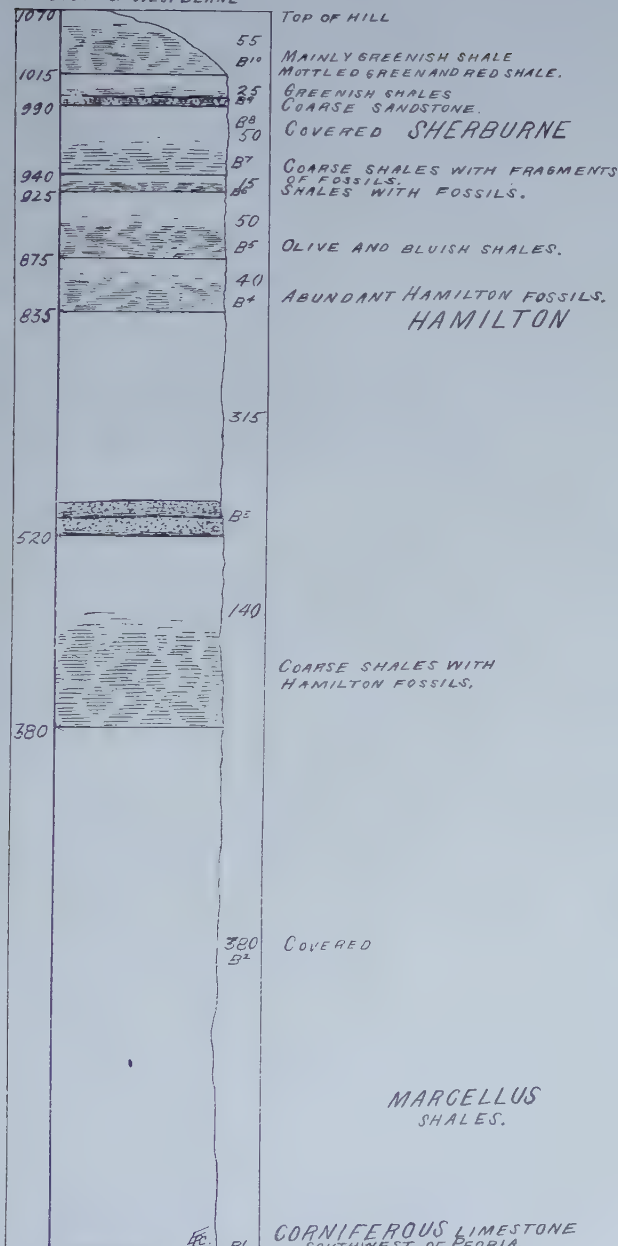
In describing the extent of the Upper Devonian formations of Albany co. we will begin with the northern township of those adjacent to Schoharie co., which is covered by these formations. Berne township lies to the east of the southern part of Wright, Middleburg and the northern part of Broome townships of Schoharie co., and to the south of Knox and north of Rensselaerville and Westerlo townships in Albany co.

XXXVIII B. The most important section studied in this township is one near its western border extending from the Onondaga limestone in the valley of the Foxkill at West Berne (Peoria) in the northwestern corner to near the base of the lowest reds on the top of Bradt hill 3.6 miles SSW of West Berne. This steep hill cut by a deep and narrow valley known as Bradt hollow with

[a] 13th an. rep't of the N. Y. state geologist, 1894, p. 229–61.

No. 38, B. SECTION OF BRADT HOLLOW & HILL

SOUTH OF WEST BERNE



frequent exposures of the Hamilton and higher rocks in its upper part makes an excellent section. In the Foxkill at West Berne are excellent outcrops of the Onondaga limestone which contain numerous corals as described by Darton.[a] The top of the Onondaga limestone is apparently shown in a small brook not far southwest of the village, but the drift has covered about all of the Marcellus shale on the hill to the south.

Along the Bradt hollow road for 380 feet above the Onondaga limestone, according to the barometer, the rocks are concealed when coarse argillaceous to arenaceous shales (B^2) containing plenty of Hamilton fossils outcrop. These fossils show that the rocks are stratigraphically above the Marcellus shales and the difference in altitude is not as great as the thickness of the rocks since the direction of the section agrees quite closely with that of the dip which is pretty heavy in this region. A stratum of quite heavy sandstone (B^3) which splits into thin layers forms a conspicuous ledge 140 feet above the shales.

XXXVIII B^4. By the side of the highway on the upper part of Bradt hill 3.4 miles SSW of West Berne and 835 feet higher than the Onondaga limestone is a fair exposure of fine, bluish argillaceous shales containing plenty of Hamilton fossils. At the base of the outcrop is a bluish sandstone two feet thick, succeeding which are rather more than five feet of the fossiliferous shales. The following species were collected:

1	*Spirifer mucronatus* (Con.) Bill.	(c)
2	*S. granulosus* (Con.) H. & C.	(rr)
3	*S. audaculus* (Con.) Whitf.	(c)
4	*Tropidoleptus carinatus* (Con.) Hall	(r)
5	*Chonetes coronata* (Con.) Hall	(r)
6	*Camarotoechia sappho* (Hall) H. & C.	(a)
7	*C. congregata* (Con.) Hall	(c)
8	*Terebratula (Eunella) lincklaeni* Hall	(rr)
9	*Productella* sp. Only fragments.	(rr)

a 13th an. rep't N. Y. state geologist, p. 243.

10	*Palaeoneilo constricta* (Con.) Hall	(r)
11	*Nuculites triqueter* Con.	(rr)
12	*Tellinopsis subemarginata* (Con.) Hall	(rr)
13	*Sphenotus truncatus* (Con.) Hall	(r)
14	*Orthonota undulata* Con.	(r)
15	*Goniophora hamiltonensis* (Hall) Miller	(r)
16	*Cimitaria elongata* (Con.) Hall	(rr)
17	*Modiomorpha subalata* (Con.) Hall	(rr)
18	*Elymella levata* Hall	(rr)
19	*Microdon (Cypricardella) tenuistriatus* Hall	(rr)
20	*Actinopteria boydi* (Con.) Hall	(c)
21	*Liopteria dekayi* Hall	(c)
22	*Pterinpecten vertumnus* Hall	(c)
23	*Homalonotus dekayi* (Green) Emm.	(rr)
24	*Taeniopora exigua* Nicholson	(c)
25	*Lingula* sp. Broken specimens	(rr)
26	*Nucula corbuliformis* Hall	(rr)

40 feet above the base of zone B^4 are greenish and bluish argillaceous shales (B^5), the interval between the two zones being partly covered. The greenish to olive shales in lithologic appearance resemble the shales of the Sherburne formation, but they alternate with bluish, slightly sandy shales which contain occasional fossils. One stratum of sandstone four to five inches in thickness contains a large number of clay pebbles.

Above this zone the rocks are again concealed for nearly 50 feet when there is another outcrop of bluish to greenish argillaceous shales (B^6) by the road side. The bluish shales contain quite a good many specimens of small Hamilton lamellibranchs as will be seen from the accompanying list. In one thin layer near the base of the zone they are specially common while a little higher is a thin layer of calcareous shell rock in which are numerous specimens of *Camarotoechia*. The fauna is:

1	*Atrypa reticularis* (Lin.) Dal.	(c)
2	*Spirifer mucronatus* (Con.) Bill.	(rr)

3 *S. granulosus* (Con.) H. & C. (rr)
4 *Chonetes setigera* Hall (rr)
5 *Orthonota undulata* Con. (c)
6 *Nuculites oblongatus* Con. (c)
Small specimens.
7 *Palaeoneilo constricta* (Con.) Hall (rr)
8 *Grammysia bisulcata* (Con.) Hall (rr)
9 *Pterinopecten vertumnus* Hall (?) (rr)

15 feet above the base of zone B^6 and 940 feet above the top of the Onondaga limestone are coarse, bluish, arenaceous shales (B^7) containing some fossils as follows:

1 *Chonetes coronata* (Con.) Hall (r)
2 *Spirifer mucronatus* (Con.) Bill. (rr)
3 *Pterinea flabella* (Con.) Hall (r)
4 *Actinopteria boydi* (Con.) Hall
5 *Nuculites oblongatus* Con.
6 Bryozoan (rr)

These are the highest rocks of the section in which Hamilton fossils were found and must be regarded as forming the top of that formation; in fact the greenish shales of B^5, 65 feet lower, are transitional from the Hamilton to the Sherburne formation and perhaps might be considered as at its top, but it is thought better to classify the succeeding 65 feet of rocks which contain a fair Hamilton fauna with that formation. The difference in altitude gives a thickness of at least 940 feet for the Marcellus and Hamilton formations in this section; but where observed there is a dip from $1\frac{1}{2}°$ to $2\frac{1}{2}°$ a mile to the southwest which would add from 475 to 780 feet, making the thickness of the formation between 1415 and 1720 feet.

For about 50 feet above zone B^7 the rocks are covered when a heavy ledge of coarse grained sandstone (B^9) varying from a slightly greenish gray to bluish gray color and splitting into thin layers which in places have a somewhat crossbedded structure, is reached in the field on the western side of the road. A little

higher on the highway and to the east are soft, greenish, argillaceous shales with occasional harder layers. About 25 feet above the sandstone is a layer of mottled red and green shale (B^{10}) by the side of the road. This is the first indication of the red rocks and the exposure is within about 50 feet of the top of Bradt hill. The top of the hill on the highway is a little north of the four corners and from the mottled shales to this point, which is about 55 feet higher, the rocks exposed are all greenish shales which apparently are in the Sherburne formation. The top of Bradt hill is 1070 feet higher than the Onondaga limestone at West Berne or barometrically some 2040 feet A. T. About three quarters of a mile to the east of Bradt hill and hollow is another high hill called West Mountain near the top of which are coarse Hamilton sandstones, the shaly layers containing abundant fossils. These sandstones varying from gray to bluish gray in color, form a conspicuous ledge on the western side of the hill, are rather coarse grained, and on the weathered surface split into thin layers from one half to one inch in thickness.

Across Bradt hollow to the northwest of Bradt hill and West mountain in Schoharie co. is Mt Sagerwana or Cotton hill, a conspicuous peak the upper 800 feet of which is in the Marcellus and Hamilton formations.

XXXVIII A^1. On the highway leading down into the valley of Stony creek above Huntersland to the southwest of the four corners on top of Bradt hill are soft, argillaceous and thin arenaceous shales in which Hamilton fossils are quite abundant. The best exposures are three quarters of a mile ENE of Huntersland and approximately 310 feet lower than the Bradt hill four corners. The following species were collected:

1	*Chonetes coronata* (Con.) Hall	(aa)
2	*Spirifer mucronatus* (Con.) Bill.	(c)
3	*S. audaculus* (Con.) Whitf.	(r)
4	*S. granulosus* (Con.) H. & C. (?)	(rr)
5	*Camarotoechia congregata* (Con.) H. & C.	(c)

6 *Orthonota undulata* Con. (c)
7 *Modiomorpha concentrica* (Con.) Hall (rr)
8 *Pholadella radiata* (Con.) Hall (rr)
9 *Grammysia bisulcata* (Con.) Hall (rr)
10 *Schizodus appressus* (Con.) Hall (rr)
11 *Pterinea flabella* (Con.) Hall (rr)
12 *Orthoceras crotalum* Hall (rr)
13 *Microdon (Cypricardella) tenuistriatus* Hall (rr)

On the highway just west of the Bradt hill four corners are green shales of the Sherburne formation.

The Turner schoolhouse, district no. 20, is at the first four corners, one mile south of the Bradt hill corners and some 60 feet lower, and on the highway not far east of the schoolhouse are red argillaceous shales. The southerly dip, however, has carried the rocks down so that these shales are stratigraphically higher than those on top of Bradt hill. These red shales form a conspicuous zone and were mapped as at the base of the Oneonta formation, which covers the high land beyond the first four corners east of the Turner schoolhouse. This region forms the high divide between the head waters of Stony brook, Tenmile creek and the Switzkill, four miles northwest of Rensselaerville and some 600 feet higher. On the divide to the west of the four corners are bluish gray thin sandstones differing inappreciably from Hamilton sandstones, while some 30 feet lower at the corners are red shales. The coarser rocks form terraces that slope rapidly to the southwest.

On comparison with the *Geologic map of New York* it will be seen that the boundary of the Oneonta formation for this region agrees closely with that outlined on the accompanying map except that on the former it is carried somewhat farther northwest, indicating that the red shales mentioned above were considered as forming its base. In fact, Darton said, "In mapping the Oneonta formation in Albany county I have assumed that its base was at the bottom of the lowest red shale member because this was the only distinguishing feature that I could use as a guide. Probably this

horizon will prove on detailed examination to be somewhat variable, but I believe not with very wide limits."[a]

About one mile south of the Turner schoolhouse and near the southern line of the township is Berne or Turner hill, the highest hill in the township and perhaps the highest in the county, being some 180 feet higher than Bradt hill or 2220 feet A. T. It forms the high divide between the head waters of Stony creek and the Switzkill on the north and Tenmile creek and other branches of Catskill creek on the south. Red shales and sandstones which are in the Oneonta formation outcrop near its summit as well as to the south in the northern part of Rensselaerville township.

In the southern part of Berne township along the principal western branch of the Switzkill are thin blue shales and sandstones, some layers of which are irregular and contain iron concretions. The bluish shales are sparingly fossiliferous, containing very mucronate specimens of *Spirifer mucronatus* (Con.) Bill., and the rocks are in the Hamilton formation. The dip is heavy to the east of south. At the bridge over this branch, one quarter mile above the Switzkill and one and one half miles northwest of South Berne are coarse blue Hamilton shales.

LV C. To the east of South Berne and the Switzkill is a steep hill known as the Agrippa hill, the crest of which is perhaps one and one half miles from, and some 500 feet higher than the Union hotel in that village. The western slope of the hill is well covered by drift but on the eastern side there are more frequent exposures of shales and sandstones. To the east is the head of the Foxkill, which has not cut so deep a valley as the Switzkill, and a section was constructed from this valley beginning perhaps one and one quarter miles WNW of Reidsville and extending to the top of the hill.

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a 13th an. rep't N. Y. state geologist, p. 240.

SECTION OF THE EASTERN SIDE OF AGRIPPA HILL

LV C

275′		Top of Agrippa hill
	77′	C^6 mainly covered
198′		
	8′	C^5 Bluish shales with abundant fossils
190′		
	15′	C^4 Bluish gray sandstone: Alexander quarry
175′		
	120′	C^3 Partly covered but showing shales alternating with sandstones
55′		C^2 Bluish sandstone: small quarry
		C^1 Bluish fossiliferous shales
0′		Head of Foxkill

The bluish argillaceous shales of C^1 are exposed along the highway near the eastern base of the hill and certain layers are very fossiliferous. The species collected are as follows:

1	*Spirifer mucronatus* (Con.) Bill.	(c)
2	*S. granulosus* (Con.) H. & C. (?)	(rr)
3	*Camarotoechia sappho* (Hall) H. & C.	(a)
4	*C. congregata* (Con.) H. & C.	(c)
5	*Tropidoleptus carinatus* (Con.) Hall	(rr)
6	*Chonetes scitula* Hall	(r)
7	*C. setigera* Hall	(c)
8	*Goniophora carinata* (Con.) Hall	(rr)
9	*Pterinea flabella* (Con.) Hall	(rr)

Above the shales of C^1 the slope is partly covered, but there are occasional ledges of thin bedded, bluish sandstone alternating with shales. Small quarries have been opened in some of these ledges, the stone splitting into six inch layers. Toward the top of the hill is the extensive flagging stone quarry known as the Alexander or Agrippa. The lower part of it (C^4) consists of 12 feet of bluish gray sandstone which is worked for flagging, sills and curbing. Near the middle is a layer unfit for use, 1 foot, 4 inches thick which splits unevenly and is called "callous" by the quarrymen. Again at the top of the even bedded sandstone are three feet of blue sandstone which is not used. The dip of the sandstone layers varies from 1° to 1½° to the southwest. Forming the upper part of the wall of the quarry are eight feet of bluish, argillaceous shales (C^5) which weather to an iron color and contain an abundant Hamilton fauna, specially Lamellibranchs. The following species were collected in these shales:

1	*Spirifer audaculus* (Con.) Whitfield	(a)
2	*S. mucronatus* (Con.) Bill.	(r)
3	*S. granulosus* (Con.) H. & C.	(rr)
4	*Productella dumosa* Hall	(c)
5	*Tropidoleptus carinatus* (Con.) Hall	(a)
6	*Dignomia alveata* Hall	(rr)
7	*Camarotoechia congregata* (Con.) H. & C.	(r)
8	*C. sappho* (Hall) H. & C.	(rr)
9	*Glyptodesma erectum* (Con.) Hall	(c)
10	*Grammysia circularis* Hall	(c)
11	*G. bisulcata* (Con.) Hall	(r)
12	*Tellinopsis subemarginata* (Con.) Hall	(r)
13	*Liorhynchus multicosta* Hall	(rr)
14	*Modiomorpha concentrica* (Con.) Hall	(r)
15	*Goniophora hamiltonensis* (Hall) Miller	(c)
16	*Nyassa arguta* Hall	(c)
17	*Macrodon hamiltoniae* Hall	(rr)
18	*Modiomorpha subalata* (Con.) Hall	(rr)
19	*Nucula corbuliformis* Hall	(r)
20	*Nuculites triqueter* Con.	(rr)

21	*Palaeoneilo plana* Hall	(c)
22	*P. perplana* (Con.) Hall	(r)
23	*Pterinea flabella* (Con.) Hall	(rr)
24	*Pterinopecten vertumnus* Hall	(r)
25	*Loxonema hamiltoniae* Hall (?)	(rr)
26	*Tentaculites attenuatus* Hall (?)	(rr)
27	*Strophalosia truncata* (Hall) Beecher	(c)
28	*Liopteria bigsbyi* Hall	(c)
29	*Aviculopecten princeps* (Con.) Hall (?)	(c)
30	*Orthoceras crotalum* Hall	(r)
31	*O. constrictum* Van.	(rr)

The above fauna shows that the quarry is in the Hamilton formation and it appears probable that it continues to the top of Agrippa hill which is only about 77 feet higher.

LV B[1]. In the southeastern part of Berne township near the head of Hannecrois creek is the little hamlet of Reidsville. In the vicinity of this village are several flagstone quarries from which large quantities of stone have been shipped. Just to the east of Reidsville is the Cumming's quarry which has the following section:

$5\frac{5}{6}'$ Soil

$3\frac{1}{3}'$ Thin bedded blue Hamilton sandstone ("callous" layer of the quarrymen)

$2\frac{1}{2}'$

$2\frac{1}{2}'$ Blue flagging sandstone which splits into layers on the average about $2\frac{1}{2}$ inches in thickness

Bottom of quarry

The dip in this quarry is about 3°S10°W

LV B². A few rods to the east of the Cumming's quarry is the Blue stone company quarry which in the lower part has five feet, eight inches of flagging stone called "blue stone" by the quarrymen. The flags split into layers varying from two and a half to three inches in thickness, while the layers from four to five inches in thickness are used for curbing. At the top of this flagging stone is a layer which thins rapidly toward the northern end of the quarry. In the southern part it is one foot, seven inches in thickness, while 100 feet farther north it has decreased to three inches. Above this are 7 feet of thin bedded sandstone, thrown away in quarrying, that contains *Spirifer mucronatus* (Con.) Bill. and plant stems. Fossils however do not occur abundantly. The section is as follows:

$12\frac{2}{8}'$		Soil
	$7'$	Thin bedded sandstone Stripping of the quarry
$5\frac{2}{8}'$		Layer of varying thickness
	$5\frac{2}{8}'$	Bluish gray sandstone Quarry stone
		Bottom of quarry

There is little soil on the rock so that the stripping is confined to the seven feet of thin sandstone layers. The following determinations of dip were made:

About 3° S10°W
2° to $2\frac{1}{2}$°W
4° SW

It varies however in different parts of the quarry since the lower layers in the northern part are nearly level. One line of joint runs S10°W and N10°E, and this is crossed by another set trending east and west.

From the above description it will be seen that the greater part of Berne is covered by the Hamilton and Marcellus formations,

the exceptions being in the northwestern and northeastern parts where the Onondaga limestone occurs, and in the southwestern where the Sherburne and Oneonta formations are found. The line between the Hamilton and Sherburne formations enters the township from Schoharie co. on the hillside to the south of Stony creek which it follows to near its head when it turns to the north and circles around the upper part of Bradt hill and then runs southeasterly into the northeastern part of Rensselaerville township. The lowest heavy line of the reds which is called the base of the Oneonta formation follows a nearly parallel course though somewhat farther to the south and west than the Hamilton-Sherburne line.

Rensselaerville

Rensselaerville lies to the south of the western half of Berne, forming the southwestern township of Albany co. It is bounded on the east by Westerlo township, on the south by Greene co. and on the west by Schoharie. Its surface is mostly high land forming either a part of the Helderberg plateau or the northeastern Catskills. Its principal streams are the Catskill creek which flows across the southwestern part receiving the Potter hollow branch from the west, both streams flanked by high and steep hills, and Tenmile creek which flows in a southerly direction across the eastern part of the township receiving Eightmile creek from the east at Medusa, and enters the Catskill creek below Oakhill in Greene co. About one mile west of Tenmile creek is a brook which flows parallel to it across the southern half of the township, entering the Catskill creek at Oakhill, which may be called the Oakhill brook.

A striking characteristic of many of the hills in this and other townships of the Helderberg region is the steep northern slope and the gradual descent to the south due to the strong dip in that general direction. An excellent illustration is afforded by the ridge to the east of Rensselaerville which ends very abruptly on the north and slopes gradually to the south. The steep northern end of this hill is clearly defined from the top of Agrippa

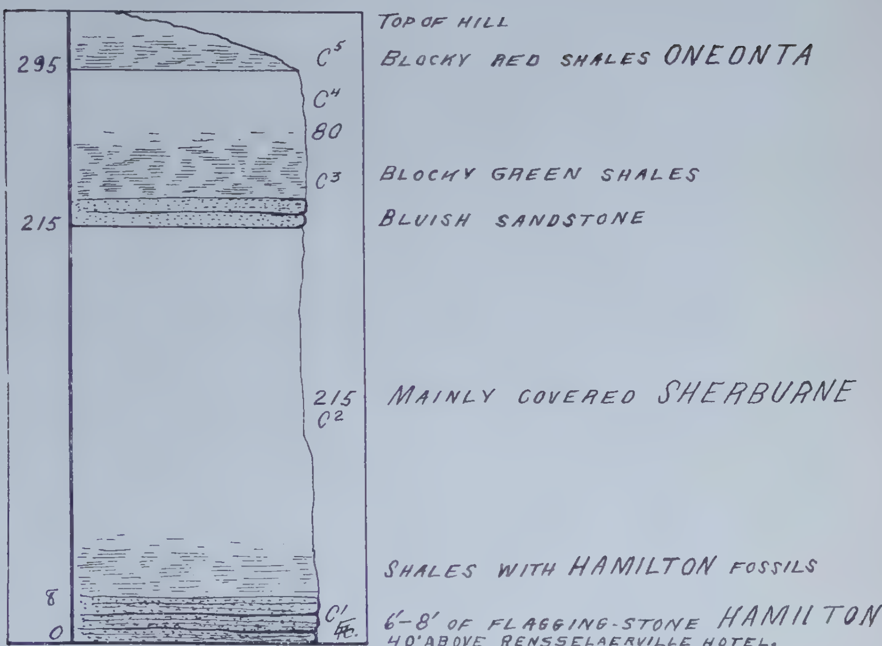
hill to the east of South Berne. The rocks in the high land of the northwestern part of the township are well covered by soil and drift and there are two small glacial lakes in the northwestern corner. Near the head of the brook which enters the Catskill at Preston Hollow, about two and one half miles west of Rensselaerville, are red shales which are approximately 950 feet higher than those on the bank of the Catskill below Preston Hollow.

LVI A^1. On the bank of the Preston Hollow brook, approximately 160 feet higher than the red shales on the Catskill is an olive shale at the base, then a crumbly, irregular shale, capped by a coarse sandstone four feet thick (A^3). Near the southern end of this cliff there is a break in the rocks with a small overthrust fault. At this place the crumbly shale is shown near the top of the cliff, while at its northern end it is not more than three feet above the water.

On the western bank of Catskill creek three fourths of a mile below Preston Hollow, and just above the bridge on the Preston Hollow-Cooksburg highway, is a fine exposure of red, argillaceous shale 20 feet thick (A^1). Near the center of the ledge is an olive band while some of it is mottled red and green. At the southern end of the cliff is a stratum of coarse grained, grayish sandstone which has either fallen or been pushed up. There is a small anticline shown in the cliff so that it is not possible to make any general estimate of the dip at this locality. These red rocks are near the base of the Oneonta formation which extends only about one mile farther south along the creek valley. This bluff of red shale is barometrically 950 feet lower than the red shale near the head of the Preston Hollow brook, 1350 feet lower than the top of Berne hill and 1100 feet lower than the base of the red shale near the Turner schoolhouse in the southwestern part of Berne township. The distance between these two localities is nine miles which gives a SSW dip of approximately 120 feet a mile.

The Oneonta formation extends up the Catskill valley from south of Cooksburg to near the county line below Living-

No. 30, C. SECTION
OF HILL 1½ MI. NORTHEAST OF
RENSSELAERVILLE



stonville where lower rocks occur. Again below Cooksburg in the northern part of Durham township, Greene co. for a few miles the creek has cut through the Oneonta formation and shows along its valley the rocks of the underlying Sherburne formation.

XXX C. The ridge to the east of Rensselaerville ends in an abrupt slope facing the valley of the Switzkill about one and one third miles directly northeast of the village. At the base of the hill is a small quarry showing some six to eight feet of blue flagging stone covered by blue argillaceous shales in which Hamilton fossils are common. These shales in lithologic characters are very similar to the typical Hamilton and the exposure is in this formation though near its top. The following species were collected and it will be seen that the fauna is very similar to that of the shales in the Agrippa quarry (55C5) near the top of Agrippa hill. It is probable that both exposures are in the same general zone of the Hamilton formation:

1	*Productella dumosa* Hall	(a)
2	*Spirifer mucronatus* (Con.) Bill.	(c)
3	*S. granulosus* (Con.) H. & C.	(c)
4	*S. audaculus* (Con.) Whitfield	(rr)
5	*Tropidoleptus carinatus* (Con.) Hall	(c)
6	*Camarotoechia prolifica* (Hall) H. & C.	(r)
7	*Chonetes mucronata* Hall	(rr)
8	*Orthothetes chemungensis* (Con.) H. & C. var. *arctostriata* Hall	(rr)
9	*Nyassa arguta* Hall	(r)
10	*Nucula corbuliformis* Hall	(a)
11	*Tellinopsis subemarginata* (Con.) Hall	(r)
12	*Palaeoneilo perplana* Hall	(rr)
13	*Sphenotus solenoides* Hall	(rr)
14	*Grammysia alveata* (Con.) Hall	(rr)
15	*G. circularis* Hall	(r)
16	*Paracyclas tenuis* Hall (?)	(rr)
17	*Glyptodesma erectum* (Con.) Hall	(c)
18	*Aviculopecten fasciculatus* Hall (?)	(a)
19	*Pterinea flabella* (Con.) Hall	(r)

20	*Actinopteria boydi* (Con.) Hall	(rr)
21	*Liopteria* sp.	(rr)
22	*Pleurotomaria sulcomarginata* Con.	(rr)
23	*Bellerophon thalia* Hall (?)	(rr)
24	*Orthoceras crotalum* Hall	(rr)
25	*Phacops rana* (Green) Hall	(rr)
26	Crinoid calyx	(rr)

Above the quarry the rocks are well covered, but about 215 feet higher than its base is a ledge of bluish sandstone on top of which are green blocky shales (C^3). Near the farm house at the northern end of the hill about 285 feet above the Hamilton fauna are blocky red shales (C^5) which show along the crest of the ridge at various places, following it to the south, and specially well on the Rensselaerville-Clarksville highway, crossing it about one mile farther south. At the four corners one and one quarter miles east of Rensselaerville is a good exposure of the red shale. To the east at the highest point on the road is red shale again and the terrace on the northern side of the road shows its rise to the north very nicely. Along the road down the eastern side of the ridge are first green shales below the reds of the terrace, then reds again showing a thickness of more than 60 feet of the Oneonta formation in the upper part of the ridge. On the road 160 feet lower than the crest of the ridge are greenish and bluish sandstones which are probably near the same stratigraphic position as the zone of XXX C^3 at the northern end of the hill. The red shales of this ridge were noted and referred to the Oneonta formation by Darton who stated that in Albany co. "From the northeastward the first exposures of the Oneonta formation are near the summit of the high ridge east of Rensselaerville, where the red shales outcrop along the road and in the adjacent fields over a narrow belt. This belt widens to the southward and covers all of the high region along the Westerlo-Rensselaerville boundary."[a]

XXX E. To the northeast of section XXX C and about two miles northeast of Rensselaerville is an excellent quarry known as the

[a] 13th annual report N. Y. state geologist, p. 239.

Plate 15

Stewart quarry north of Rensselaerville; Hamilton flagstone

Stewart flagstone quarry from which a large amount of flagging has been shipped. There is from four and a half to six feet of good flagging stone that splits into layers, three, four and eight inches in thickness covered by 11 feet of stripping composed of shale and soil. The blue argillaceous shales on top of the flagging stone contain an abundant Hamilton fauna and the rocks belong in the upper part of that formation. The following species were collected:

1	*Spirifer granulosus* (Con.) H. & C.	(c)
2	*S. mucronatus* (Con.) Bill.	(r)
3	*Tropidoleptus carinatus* (Con.) Hall	(c)
4	*Camarotoechia prolifica* (Hall) H. & C.	(rr)
5	*Orthis (Rhipidomella) vanuxemi* Hall (?) Internal impression poorly preserved.	(rr)
6	*Orthothetes chemungensis* (Con.) H. & C. var. *arctostriata* Hall	(rr)
7	*Productella dumosa* Hall	(r)
8	(?) *Orbiculoidea* sp.	(r)
9	*Orthonota* (?) *parvula* Hall	(rr)
10	*Nucula corbuliformis* Hall	(c)
11	*N. Varicosa* Hall	(rr)
12	*Palaeoneilo perplana* Hall	(rr)
13	*Grammysia circularis* Hall	(r)
14	*G. lirata* Hall	(rr)
15	*Modiomorpha subalata* (Con.) Hall (?)	(rr)
16	*Goniophora hamiltonensis* (Hall) Miller	(rr)
17	*Glyptodesma erectum* (Con.) Hall	(r)
18	*Aviculopecten fasciculatus* Hall (?)	(c)
19	*Actinopteria boydi* (Con.) Hall	(rr)
20	*Bellerophon brevilineatus* Con.	(rr)
21	*B. thalia* Hall	(rr)

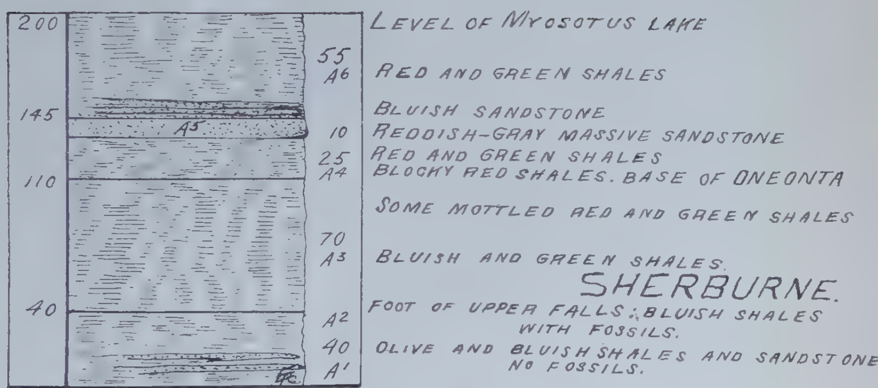
This quarry is nearly two and a half miles southwest of the Agrippa quarry on the hill east of South Berne and the dip is about $1\frac{1}{2}°$ S 35° E. The accompanying picture serves as a fair illustration of the flagstone quarries in the upper Hamilton of Albany county and gives a clear idea of the one just described.

XXX A[1]. Tenmile creek flows through the western part of Rensselaerville village forming a glen of some depth. In the lower part of the glen about opposite the village hotel are ledges of shales and sandstones. Part of the shales are of an olive color and argillaceous, splitting into very small pieces while others are more blocky in texture and mottled blue and greenish in color. The sandstones contain numerous irregular, fucoidal-like markings on the surface of the different layers. Again the surface of some of the layers is irregular as though deposited in shallow water where they were affected by currents and waves. The appearance of these rocks is similar to that of the transitional Hamilton in the North Blenheim region of the Schoharie valley. No fossils were found.

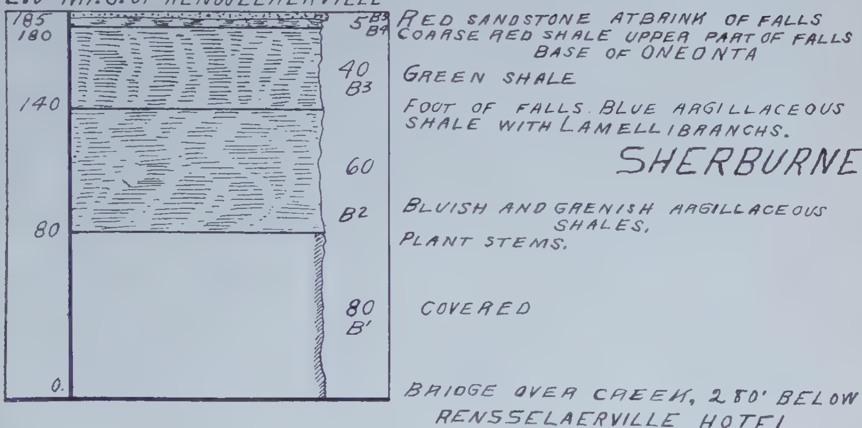
XXX A[2]. Above the lower falls and bridge and extending to the foot of the principal fall 40 feet above the base of the section which is only a short distance west of the village, are bluish shales, some of the layers forming a fairly hard sandstone in which fossils are common. The smooth shales alternating with these coarser layers contain very few, if any, fossils. The following species were obtained from the sandy layers of this zone:

1	*Camarotoechia prolifica* (Hall) H. & C.	(c)
2	*Spirifer granulosus* (Con.) H. & C.	(c)
3	*S. mucronatus* (Con.) Bill.	(rr)
4	*Chonetes setigera* Hall	(rr)
5	*Strophalosia truncata* (Hall) Beecher (?)	(r)
6	*Goniophora hamiltonensis* (Hall) Miller	(r)
7	*Grammysia magna* Hall	(rr)
8	*Palaeoneilo constricta* (Con.) Hall	(r)
9	*Orthonota undulata* Con.	(rr)
10	*Nyassa arguta* Hall	(rr)
11	(?) *Sphenotus truncatus* (Con.) Hall Quite imperfect specimens.	(rr)
12	*Pterinea flabella* (Con.) Hall	(r)
13	*Actinopteria boydi* (Con.) Hall	(r)
14	*Loxonema hamiltoniae* Hall	(rr)
15	*Tentaculites attenuatus* Hall	(rr)
16	*Taeniopora exigua* Nicholson	(c)

No. 30, A. SECTION OF GLEN AT RENSSELAERVILLE



No. 30, B. SECTION
OF
FELTER'S GLEN
2.8 MI. S. OF RENSSELAERVILLE



The above is a Hamilton fauna and apparently these shales are at the top of that formation as shown by the higher rocks.

Succeeding the fossiliferous shales at the foot of the falls are bluish and greenish shales (A^3) with some mottled red and green shale in the upper part. At an elevation of 70 feet above the foot of the fall is a stratum of red, blocky shale (A^4) succeeding which are 25 feet of alternating red and green shales extending up to a massive sandstone which forms the brink of the upper falls. The red shale at the base of this zone was taken for the base of the Oneonta formation and is so represented on the accompanying map. If it represents the same zone as XXX C^5 at the northern end of the ridge 1.7 miles to the northeast then the dip to the sw is 153 feet a mile.

At the top of the falls is a massive reddish gray sandstone (A^5) 10 feet or more in thickness, the top of which is 145 feet above the base of the section. On this massive sandstone are thinner bluish sandstones. In the wall of the dam is a large block in which are the following species:

1	*Spirifer granulosus* (Con.) H. & C. (?)	(r)
2	*S. mucronatus* (Con.) Hall	(rr)
3	*Chonetes coronata* (Con.) Hall	(rr)
4	*Camarotoechia prolifica* (Hall) H. & C.	(rr)
5	*Orthis (Rhipidomella) vanuxemi* Hall	(rr)

Farther up the creek are reddish, greenish and mottled shales (A^6) which extend to the dam at the lower end of Myosotus lake 200 feet above the base of the section. The above section is shown in tabular form in the reproduced diagram.

XXX B^1. Two and eight tenths miles to the sse of Rensselaerville is a gorge known as Felter's glen which has been cut by an eastern branch of Tenmile creek. The lowest rocks (B^2) which are green argillaceous shales occur about 80 feet higher than the highway bridge. Above these occur layers of bluish sandstone with a slightly reddish tint, which contain sand holes and plant stems. These rocks are referred to the Sherburne formation on account of their stratigraphical position, lithological appearance and the

absence of fossils. Some 60 feet higher than the lowest shales at the foot of Felter's falls is a layer of blue, argillaceous shale (B^3) in which *Estheria* sp. are common. Dr John M. Clarke after examining them says "I know no other species in our Devonian except my *E. pulex*, which is a little fellow." (Letter, dated Mar. 21, 1898)

Immediately above the blue shales are smooth, green shales breaking into irregularly shaped pieces in which no fossils were found. The green shales are about 40 feet thick, but in the upper part of the falls and the rocky sides of the glen are coarse, blocky, red and mottled shales (B^4). This zone is five feet thick and part of it is very arenaceous almost forming a sandstone. This stratum is the lowest of the clearly red rock seen in the glen and is called the base of the Oneonta formation. If the lowest red shale (XXX A^4) in the Rensselaerville glen is at approximately the same stratigraphical position then there is a dip to the sse of 62 feet a mile. It appears probable that the red shale of XXX C^5 at the northern end of the ridge 3.7 miles north of Felter's glen represents about the same zone as B^4 in this glen which gives a dip directly south of 117 feet a mile.

Directly on the top of the zone of red shale and 185 feet higher than the base of the section is a red sandstone (B^5) which forms the brink of Felter's falls. Above the falls for a short distance are greenish, irregular shales, then red and mottled red and green argillaceous shales, but after a few rods the rise is very gradual and the rocks are concealed by drift. The red shales are shown at various places along the ridge to the north of Felter's glen toward the Rensselaerville-Clarksville highway and also on the sides of the hills flanking Tenmile creek to the south of the glen. On the western side of Tenmile creek on the highway a short distance north of Medusa and five miles south of Rensselaerville are red argillaceous shales 125 feet above the bed of the creek in the village, while on the same road just north of Medusa are mottled red and green shales only 45 feet above the creek level. In the creek bed from the highway bridge to the foot of the dam are greenish and bluish shales and sandstones apparently

in the upper part of the Sherburne formation. This upper part of the Sherburne formation is shown at various places along the lower valley of Tenmile creek to its junction with the Catskill in the northern part of Greene co. and for some distance along the valley of the latter creek both below and above the mouth of Tenmile creek. The lower line of the Oneonta formation along these two creeks is quite accurately shown on the *Geologic map of New York* except that it is carried several miles too far down the Catskill creek valley.

Westerlo

To the east of Rensselaerville and south of the eastern half of Berne township is Westerlo which occupies a central position in the southern tier of townships in Albany co. The principal streams are Basic creek which rises in the northern part and flows southerly across the central part of the township, Eight Mile creek which rises in the western part and flows southwesterly into Tenmile creek and Hannecrois creek which flows across the northeastern portion of the township. The general elevation is less than that of Rensselaerville or Berne townships and the various ridges extending in a general north and south direction are not as steep. The western half of the township is quite heavily covered with drift so that any considerable exposures of the underlying rocks are infrequent.

XXX D^1. On the western side and near the top of the low hill about one half mile west of Dormansville is one of the Dormansville flagstone quarries. At the base are three and a half feet of bluish flags on a weathered surface turning slightly reddish, the shaly partings of which contain fossils. Above are eight feet of bluish, argillaceous, somewhat blocky shales which are quite barren of fossils, next, a stratum of sandstone one and a half feet in thickness covered by another stratum of somewhat blocky, argillaceous shales in which small Hamilton lamellibranchs are abundant. These rocks have the lithological appearance of the Hamilton and contain its fauna and are clearly in this formation. The following species were collected:

1 *Spirifer mucronatus* (Con.) Bill. (a)
2 *Tropidoleptus carinatus* (Con.) Hall (c)
3 *Chonetes coronata* (Con.) Hall (c)
4 *C. setigera* Hall (c)
5 *Camarotoechia sappho* (Hall) H. & C. (r)
6 *C. prolifica* (Hall) H. & C. (rr)
7 *C. congregata* (Con.) H. & C. (r)
8 *Leda diversa* Hall (rr)
9 *Goniophora rugosa* (Con.) Miller (rr)
10 *Nuculites oblongatus* Con. (rr)
11 *Sphenotus truncatus* (Con.) Hall (?) (c)
Imperfectly preserved. Somewhat resembles *Nyassa recta* Hall.
12 *Nucula bellistriata* (Con.) Hall (a)
The specimens are smaller than the figures of this species and are apparently the young, or perhaps the variety noted in the Ithaca at Oneonta.
13 *Nyassa subalata* Hall (?) (r)

XXX D^2. Just over the hill mentioned above on its eastern side is a larger quarry, nearly 10 feet of flagging stone showing in its lowest part. The sandstone is the same stratum as the flagstone of the other quarry and the quarry is much better not only on account of the greater thickness of the rock but also because there is very little shale on top of the flags and consequently less stripping. A thin sandstone in the shales near the quarry contains immense numbers of very mucronate specimens of *Spirifer mucronatus* (Con.) Bill. associated with *Chonetes coronata* (Con.) Hall. The complete list is:

1 *Spirifer mucronatus* (Con.) Bill. (a)
2 *S. sculptilis* Hall (r)
3 *Chonetes coronata* (Con.) Hall (a)
4 *Tropidoleptus carinatus* (Con.) Hall (a)
5 *Camarotoechia congregata* (Con.) H. & C. (c)
6 *Sphenotus truncatus* (Con.) Hall (rr)
7 *Glyptodesma erectum* (Con.) Hall (r)
8 *Bellerophon patulus* Hall (?) (rr)
Imperfectly preserved.

In places the rock shows a dip of between 2° and 2½° S about 40° W.

The Dormansville quarries were mentioned by Darton who states that they "are in a bed about 10 feet thick which yielded a very large amount of excellent flagging."[a] Darton divided the Hamilton of Albany co. into two divisions, the lower one 600 feet in thickness, which he called the "Hamilton black shales" and the upper one the "Hamilton flags and shales" 700 feet in thickness. He considered that "The beds of flags are not at any definite horizon, though the greater amount of flag which has been worked is from beds about 250 feet above the base of the series [his upper division]. . . The lower portion of the formation is sparingly fossiliferous, particularly some of the softer thinner flags, which yield a Hamilton group fauna. The upper beds of the series may extend above the limits of the Hamilton group of western New York, but I have at present no definite evidence on this point."[a]

It seems that all of the important flagstone quarries of Albany county are in the Hamilton formation, as stated above, but it will be shown that farther south in Greene and Ulster counties many of the large quarries are above the Hamilton and in the Sherburne formation. Again the writer considers that in Albany county the upper portion of Darton's "Hamilton flags and shales" are above the top of the Hamilton as he thought they might be and in the Sherburne formation.

On the hill east of Basic creek and some three miles northeast of South Westerlo is a prominent ledge (XXX D[3]) of massive red sandstone five feet in thickness. The surface is very irregular as though it had been worn by the ice. In the field to the east of the highway is a ledge some 15 feet in thickness. At the base is apparently a stratum of red sandstone, then there are bluish gray sandstones which are capped by red somewhat irregularly bedded sandstones. In the southeastern part of the township about three miles east of South Westerlo are coarse, arenaceous shales and

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a 13th annual report N. Y. state geologist, p. 241.

thin blue sandstones (XXX D[5]) which have the lithologic characters of the Hamilton. In places they contain the characteristic fauna of the coarse Hamilton deposits as *Spirifer granulosus* (Con.) H. & C., *Spirifer mucronatus* (Con.) Bill., *Chonetes coronata* (Con.) Hall, etc. the complete list being:

1	*Chonetes coronata* (Con.) Hall	(a)
2	*Tropidoleptus carinatus* (Con.) Hall	(c)
3	*Spirifer mucronatus* (Con.) Bill.	(r)
4	*S. sculptilis* Hall	(rr)
5	*S. granulosus* (Con.) H. & C.	(rr)
6	*Camarotoechia prolifica* (Hall) H. & C.	(c)
7	*C. sappho* (Hall) H. & C.	(rr)
8	*Orthothetes chemungensis* (Con.) H. & C. var. *arctostriata* Hall	(c)
9	*Glyptodesma erectum* (Con.) Hall	(c)
10	*Nucula bellistriata* (Con.) Hall	(rr)
11	*Nyassa subalata* Hall	(r)
12	*Platyceras bucculentum* Hall (?)	(rr)

The rocks of this locality are undoubtedly in the Hamilton formation. Near the highway corners one mile to the west of the Hamilton rocks is red sandstone of the Oneonta formation while below are greenish shales and sandstones, in which no fossils were found, that are probably in the Sherburne formation. The red sandstone is 150 feet higher than the Hamilton exposure to the east and supposing the dip to be 100 feet a mile to the west which is apparently all that it is, then the red sandstone is approximately 250 feet stratigraphically above the Hamilton.

On top of the hill one half mile east of South Westerlo is a prominent ledge of greenish red sandstone (XXX D[6]) five feet in thickness which on the weathered surface has a dark red color. Above is a ledge of clear blue, thin sandstone which is cross-bedded. On the *Geologic map of New York* the exposures of red rock just described are mapped as in the Hamilton formation which is represented as covering all of the country to the east of Basic creek, its top occurring on the hills considerably west of the creek and South Westerlo. Along Basic creek above and

below the bridge at South Westerlo are ledges of rather greenish sandstone and some shales in which no fossils were found. These rocks are 100 feet or more below the red sandstone on top of the ridge east of the creek and are in the Sherburne formation which extends down the creek into the northern part of Greenville township in Greene co.

The exposures in Westerlo and Rensselaerville townships show that red and gray rocks in lithological characters identical with the typical Oneonta formation have replaced the Ithaca formation, and that the reds appear at lower and lower stratigraphic horizons as the strike of the formations is followed southeasterly from Schoharie co.

The line of division between the Hamilton and Sherburne formations enters Rensselaerville from Berne township about north of Rensselaerville village, runs southerly into the Switzkill valley, then about easterly around the northern end of the ridge to the east of Rensselaerville village and then in a general southeasterly direction across Westerlo township. The line is somewhat to the west of Westerlo (Chesterville) and Dormansville and leaves the township near its southeastern corner, three miles east of South Westerlo. The drift conceals the older rocks so thoroughly over a large part of Westerlo that it is difficult to trace the line of separation between the different formations. The red shale and sandstone at the base of the Oneonta formation is a much more irregular line than the one between the Hamilton and Sherburne formations. The red shale enters Rensselaerville township near the middle of its northern line to the west of the Switzkill, shows in the gorge of Tenmile creek west of Rensselaerville village and then runs about southerly on the eastern side of the hill to the west of this creek to its end east of Oak Hill in the northern part of Durham township Greene co. Then it extends up the valley of the Catskill across the line into Rensselaerville township below Cooksburg where it crosses the creek and follows the western side to below Eagle bridge more than one mile below Oakhill, then it crosses the Catskill back to the east and follows the western side of the ridge east of Tenmile creek to its

northern end northeast of Rensselaerville village. From the northern end of the above ridge the direction is in general southeasterly across the southwestern portion of Westerlo in the valley of Basic creek, which it crosses below South Westerlo, in the northern part of Greenville, Greene co. and runs northeasterly along the ridge east of the creek and South Westerlo till it turns southeasterly again and crosses the line into Greenville about two miles east of South Westerlo. It will be noticed on referring to the accompanying geological map that in the southern part of Albany and northern part of Greene counties the boundaries of the formations make frequent loops to the north, and this is caused by the abrupt northern ends of the ridges between the streams which have a generally southerly direction, so that a line follows down the flank of a hill on the western side of a stream till it crosses it when it follows the rise of the ridge on the east frequently till it makes the turn around its northern end. As already stated the red rocks of the Oneonta formation extend considerably farther east along the southern line of Westerlo than is represented on the *Geologic map of New York* since they cross Basic creek to the east below South Westerlo and run southeasterly across the northeastern part of Greenville township instead of keeping to the west of Basic creek until several miles below West Greenville.

GREENE COUNTY

Greene co. lies to the south of Albany and the eastern part of Schoharie co. and extends eastward from Delaware co. to the Hudson river. The Schoharie river rises in the Catskills, which cover the western half of the county, and flows in a northwesterly direction till it enters Schoharie co. The eastern face of the high land or plateau out of which the Catskill mountains have been carved by denudation ends abruptly, and when seen from the comparatively low land between the mountains and the Hudson river has the appearance of a high and massive mountain range. To the east of the mountains is a rolling country with low and generally rounded hills till the limestone ridges are

reached to the west of the immediate valley of the Hudson river when we find folded rocks forming steep hills of considerable elevation, composed of the formation belonging in the upper Silurian system and the lower Devonian which extend across the county with a ssw trend about parallel to the course of the river. The principal streams to the east of the Catskill mountains are the Catskill creek from the northwest and the Kaaterskill from the southwest which unite just after cutting through the sharply folded limestone hills west of Catskill and enter the Hudson river near that town. The rolling country to the west between these hills and the base of the mountains is composed mainly of the Hamilton, Sherburne and lower part of the Oneonta formations, while from the upper part of the eastern border range of the Catskill mountains westward across the county into Delaware and southward across Ulster co. the rocks belong in the Catskill formation.

Northern townships

The northern tier of townships in Greene to the south of Albany co. is composed from east to west of New Baltimore, Greenville and Durham. The great amount of drift found in New Baltimore and Greenville townships similar to that already mentioned in reference to Westerlo rendered it extremely difficult to trace the top of the Hamilton formation. Only a few exposures yielding Hamilton fossils were found in New Baltimore township but this was due in part to the fact that the country examined somewhat carefully was found to be underlaid by rocks near the top of that formation and above it in the Sherburne. By the side of the road in the hamlet of Medway are bluish shales containing a few Hamilton fossils, and the rocks are clearly in that formation. The species collected are:

1 *Camarotoechia prolifica* (Hall) H. & C. (c)

2 *Nucula corbuliformis* Hall (?) (rr)

Broken and poorly preserved specimens.

3 *Tentaculites* sp. (rr)

4 Crinoid segments (c)

One and one fourth miles northwest of Medway is the Medway Park hotel and by the side of the small pond to the north of it are fine, bluish argillaceous shales which contain a few Hamilton fossils and are evidently in that formation. The list is as follows:

1	*Chonetes coronata* (Con.) Hall	(c)
2	*C. setigera* Hall	(a)
3	*Spirifer mucronatus* (Con.) Bill.	(c)
4	*Camarotoechia prolifica* (Hall) H. & C.	(c)
5	*Nuculites oblongatus* Con.	(rr)
6	*Tentaculites* sp. Imperfectly preserved.	(r)

On the northern road from Medway Park hotel to Grapeville near the top of the ridge between the two branches of Cabin river are fossiliferous rocks which are also apparently in the Hamilton as will be seen by the following species:

1	*Spirifer mucronatus* (Con.) Bill.	(c)
2	*Chonetes coronata* (Con.) Hall	
3	*Camarotoechia prolifica* (Hall) H. & C.	(r)
4	*Orthonota* (?) *parvula* Hall	(rr)
5	*O. carinata* Con.	(rr)

The top of the same ridge however on the southern road one half mile farther south is composed of rather greenish, unfossiliferous shales similar in lithologic appearance to the Sherburne. On the highway to the east of Cabin river one mile below Grapeville and 150 feet lower than the greenish shales on top of the ridge to the northeast are bluish shales containing Hamilton fossils. Passing westward these were the last Hamilton fossils seen and the top of the Hamilton has been represented as crossing from Westerlo the northeast corner of Greenville into New Baltimore township. Then it runs along the western side of Cabin river as far perhaps as one mile below Grapeville, when it crosses the river, makes a loop round the ridge on the eastern side and follows that southeasterly toward Urlton (formerly Jacksonville) in Coxsackie township. There are possibly reddish rocks on the ridge west of Grapeville, but one and one half miles farther west on the ridge east of East Greenville are clear red

argillaceous shales. A mile east of the village is a good exposure of the red shales and along the highway from East Greenville to Greenville are several outcrops of red shale and sandstone. At the top of the hill just east of Greenville are thin red sandstones. The base of the Oneonta formation is represented on the map as crossing the northeastern part of Greenville township to the east of East Greenville and the southwestern corner of New Baltimore into the northwestern corner of Coxsackie township. This line of the base of the reds or Oneonta formation is represented on the *Geologic map of New York* as on the ridge west of the creek at West Greenville, while as a matter of fact it is on the Norton hill—East Greenville highway four and one third miles farther east.

LVII D^2. From East Greenville across the northern part of Greenville and Durham townships the rocks all belong in the Oneonta formation till the valley of Tenmile creek is reached east of Oakhill in Durham. Not much above the creek's mouth by the highway and opposite the mill on its western bank are fine blue argillaceous shales and a layer of them 30 feet above the level of the creek contains numerous specimens of:

1 *Estheria* sp. (a)
2 *Beyrichia* sp. (c)

These shales are in the Sherburne formation which as already described extends up the creek valley to Rensselaerville and down it to below its mouth on the Catskill.

Red argillaceous shales occur on the road across the southern end of Pine Tree hill which forms the divide between Tenmile and Kelsey creeks, 160 feet above the level of Tenmile creek at the mill or 110 feet above the creek level at the first bridge north of the mill. These shales were regarded as the base of the Oneonta formation and occur at the same position as represented on the *Geologic map of New York*. From the base of the red shales to the top of Pine Tree hill on the road toward Medusa there are 95 feet of red shales with some greenish layers. Near the "pine tree" on the road across the southern end of the hill one half mile northeast of Oakhill there is an outcrop of red

shale some 220 feet above the Catskill creek level in Oakhill. This exposure is apparently about 100 feet above the base of the Oneonta, but the rocks are covered by drift along the road down the western side of the hill.

LVII A[1] At Oakhill Kelsey's creek flows into the Catskill from the north. In the lower part of the glen just above the street bridge and 15 feet above the level of Catskill are blue, argillaceous shales which contain specimens of *Estheria* sp. apparently the same as those found at the foot of Felter's falls in Rensselaerville township. Higher in the glen are green argillaceous shales, which belong in the Sherburne formation that extends up this creek for a distance, and greenish sandstone with some that is dark gray in color. Loose pieces of red sandstone were also noticed in the upper part of the glen. It is reported by some of the residents of Oakhill that natural gas comes to the surface just above the street bridge in Kelsey's creek. Red shale and sandstone show on the highway three fourths of a mile northwest of Oakhill not far below the first cross road across the creek, and about 225 feet above the level of the Catskill in Oakhill. On the cross road is an outcrop of red shale with some that is green in color 115 feet higher than the creek at Brown's mill. Red sandstone forms a ledge on the western bank of Catskill creek rather more than three fourths of a mile above Brown's mill and not far below Cooksburg. This ledge according to the contour lines on the "Durham sheet" of the United States topographic map has an altitude of about 740 feet above sea level. From this locality the base of the red rocks were followed southeasterly along the western side of Catskill creek. In the brook below Durham village the lowest red rocks seen are shales which occur at an elevation of 720 feet A. T. Below this outcrop the rocks are mostly covered along this brook and this shale may not be at the base of the reds. In a small brook entering the Catskill from the west at Eagle bridge and mill, one mile below Oakhill are red shales only 30 feet above the level of the creek and below them along the brook and on the bank of the creek are bluish and olive argillaceous shales which are probably at the

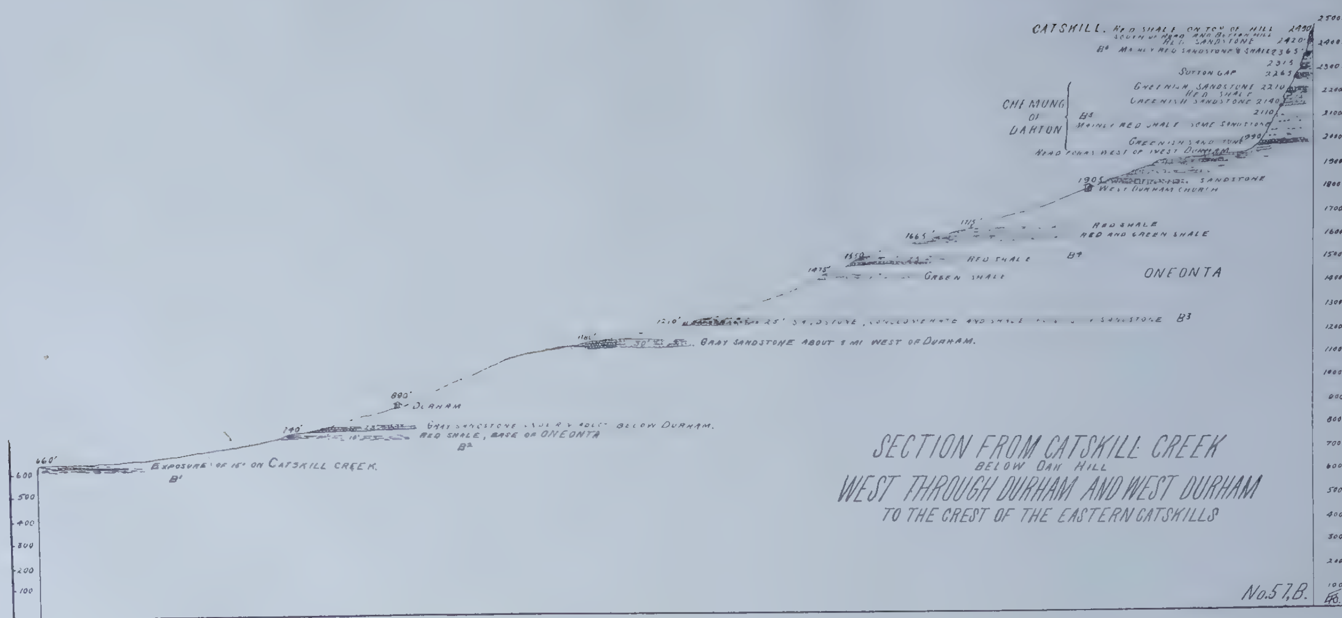
top of the Sherburne formation. The dip is $2\frac{1}{2}°$ S, 60° E on the bank of Catskill creek below the bridge. The red shales at this locality are considered to be the base of the Oneonta formation which does not extend much farther down the creek. On the *Geologic map of New York* the base of the Oneonta formation is represented about three miles farther down the creek near East Durham, but there are occasional exposures of the red rocks along the creek between the two localities. The bed of Catskill creek east of East Durham is composed of red sandstone while on the western bank one mile above the East Durham bridge there is a ledge 25 feet high composed of red shales alternating with grayish and greenish shales and sandstones. There is a heavy dip to the SE along this part of the creek valley.

LVII B On the western bank of Catskill creek just below the highway bridge, a short distance south of Oakhill, are ledges 15 feet in thickness (B^1). These rocks are mainly greenish argillaceous shales with some bluish shale and alternating with them are sandstone layers. The sandstones are bluish to greenish in color and the fine greenish shales contain plenty of concretions of iron pyrites, which in weathering stain them in spots and streaks a rusty color. Loose in the creek is a large conglomerate boulder containing some quartz but a much larger number of clay pebbles. The dip at this locality is about 3° S, 60° E; while directly south the rocks appear to lie nearly horizontal. In this region of southern Albany and northern Greene counties there has been apparently some gentle folding which is well obscured by the heavy covering of drift. No fossils were found in these rocks which are in the upper part of the Sherburne formation. Near the above locality a stream enters Catskill creek from the west which I have called Durham creek, and a section along this creek and highway from the creek through Durham and West Durham to the crest of the eastern line of the Catskills was carefully studied. The various outcrops found along this section are shown on the following diagram in which the altitudes are based upon the contour lines of the "Durham sheet" of the United States geological survey.

The rocks along the lower part of Durham creek are mostly covered; but about 80 feet higher than the Catskill creek level is an outcrop of red argillaceous shale (B^2) in its bed. This locality is below Durham just beyond the house of Noah Scutt, where there is perhaps in all a 10 foot ledge with three feet of red shale at the base. This ledge is in the red rocks of the Oneonta formation near, if not quite at, its base, and is apparently at the same locality at which the base of the Oneonta formation is represented as crossing this creek on the *Geologic map of New York*. A little higher below and under the viaduct just east of Durham village are 23 feet of bluish sandstone with some greenish argillaceous shale partings. No fossils were found in these rocks. The dip varies considerably in amount even in a short distance, as for example at the base of this outcrop it is about $\frac{1}{2}°$ to the SW and 2° S, while above the viaduct it is $5\frac{1}{2}°$ S. It is rather difficult however to determine the amount of the dip accurately on account of some irregular bedding in the rocks. On the highway about one mile west of Durham are coarse grained, irregularly bedded, grayish to greenish gray sandstone in thin layers, 30 feet or more of which are exposed. In the upper part of this outcrop some 550 feet higher than Catskill creek is a thin layer of bluish sandstone (B^3) containing fossils. The list is as follows:

1	*Spirifer mucronatus* (Con.) Bill. Small specimens.	(c)
2	*Orthothetes chemungensis* var. *arctostriatus* (Hall) H. & C.	(a)
3	*Tropidoleptus carinatus* (Con.) Hall	(r)
4	*Homalonotus dekayi* (Green) Emm.	(rr)
5	*Nuculites triqueter* Con.	(rr)
6	*Chonetes scitula* Hall	(c)
7	*Palaeoneilo constricta* (Con.) Hall	(rr)

Above the fossiliferous layer is a thin stratum of conglomerate possibly one foot in thickness. This outcrop is by the roadside just below the E. A. Moss house one mile west of Durham village, opposite the 25th mile post and a little below the crossroad to the



SECTION FROM CATSKILL CREEK
BELOW OAK HILL
WEST THROUGH DURHAM AND WEST DURHAM
TO THE CREST OF THE EASTERN CATSKILLS

south. Loose shales were also found at this place which contain a fair number of fossils, apparently Hamilton species. Perhaps the shales are from a boulder though they are lumpy as though they had not been transported very far.

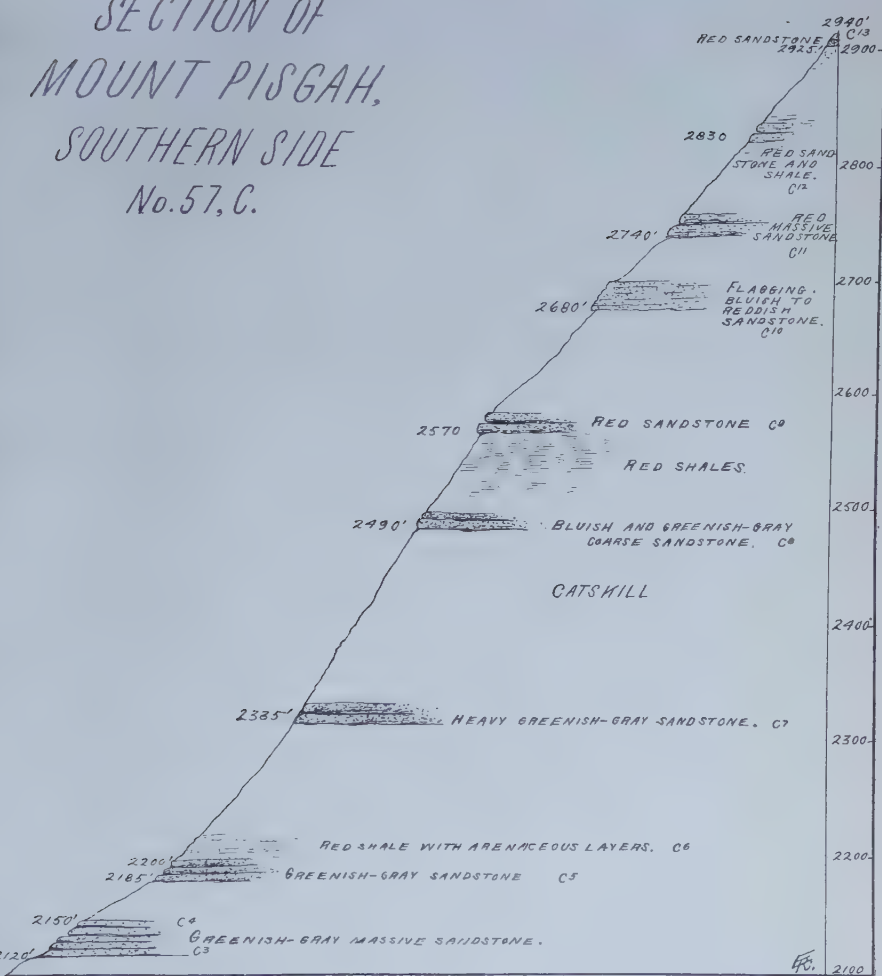
The fossiliferous layer described above occurs 475 feet higher than the red shales of B^2 in the creek below Durham. Red shales and sandstones are conspicuous at various localities on the western side of Catskill creek below this fossiliferous bed and all of that region is colored as in the Oneonta formation on the *Geologic map of New York.* This classification has been accepted by the author for the purpose of geological mapping for, on account of the almost entire absence of fossils it would be next to impossible to draw a line separating these formations unless some prominent lithologic character like the first appearance of the reds be selected for such purpose. Such a line is not a continuous one for it represents horizons of somewhat different geological age at different localities, but perhaps it is as good a method as can be devised for the separation of these rocks. It seems to the author that this lentil of fossils 475 feet above the base of the reds shows conclusively that the reds in Albany and Greene counties appeared near the close of the Sherburne and practically replaced the Ithaca formation by rocks which are indistinguishable from those of the Oneonta formation. On the road 815 feet higher than Catskill creek are greenish argillaceous shales containing fragments of plant stems. Greenish and reddish shales, the reds rather arenaceous, occur 75 feet higher. At the base is a grayish sandstone and the entire outcrop is 25 feet in thickness. This locality is on the road just east of the stone schoolhouse and one mile east of West Durham. At the forks of the road just west of West Durham and the cemetery are coarse, greenish sandstones alternating with red and green shales, 1330 feet higher than Catskill creek. Glacial striae show very well on top of the greenish gray sandstone running about W, 10° N, and E, 10° S. Below the fork toward West Durham there is greenish sandstone alternating with reddish shale, but for 50 feet or more the sandstone predominates. Just above the fork on the road turning

south is a good exposure of red shale. On the *Geologic map of New York* the base of the Chemung is represented as crossing the highway just above this fork which is 1260 feet or more above the lowest reds seen in Durham creek. This would give a thickness of 1250 to 1300 feet for the Oneonta formation. Above the road fork on the southern road there are 120 feet of nearly continuous outcrops of rocks which are mostly reddish shales with some greenish streaks. Lithologically they are not different from the reds of the Oneonta below or those of the Catskill above. On account of the supposed Chemung age of the rocks for the succeeding 250 feet the outcrops from this fork to the Sutton gap were carefully examined by my assistant in the Greene county field work, Mr R. B. Rowe, and myself.

As already stated, from the top of the greenish sandstones at the road forks 1990 feet A. T., for 120 feet the rocks are mainly red shales, as shown on the south road, on the western road at 2140 feet A. T. is red shale which contains the branching plant-like form not uncommon in the Catskill rocks. This is succeeded by massive gray sandstone which is partly covered in the field but apparently extends to 2210 feet A. T. with a stratum of red shale near the middle of the zone. About 55 feet higher is the Sutton gap pass which on the *Geologic map of New York* is represented as at the base of the Catskill formation. The position and character of these rocks which have been referred to the Chemung are well shown in B^5 of the accompanying section. Mr Darton described these so-called Chemung rocks as follows: "This mass becomes harder and coarser eastward and was traced to and along the eastern front of the Catskill mountains, its base defining the upper limit of the Oneonta formation. Its thickness averages about 250 feet. It is overlain by a red shale bed 25 to 30 feet in thickness and this in turn is overlain by the thick mass of hard, gray sandstone on which the old Mountain house is built. At a point about four miles due west of Durham some molluscan remains were found in a softer gray bed about 175 feet above the summit of the Oneonta formation. One fairly distinct individual

SECTION OF MOUNT PISGAH, SOUTHERN SIDE

No. 57, C.



was recognized by Dr Hall as *Spirifer disjunctus*, a Chemung form."[a]

In our search we were not successful in finding fossils in this zone except *Lepidodendron* sp. and fragments of plant stems. It is very evident however that there are no 250 feet of coarse, gray sandstones, but in the upper half of the zone are heavy layers of grayish to greenish gray sandstones alternating with red shales and sandstones. The lower half of the zone is composed largely of red rocks, but in the upper half there are two heavy ledges of the greenish gray sandstones separated by red and green shales with a thickness of from 70 to 80 feet. On the hill to the south of the pass the rocks are largely red shales and sandstones with some layers of greenish sandstone. This hill is mapped as in the lower part of the Catskill formation on the *Geologic map of New York* and it has an approximate altitude of 2490 feet A. T.

LVII C. To the southeast of the point just described on the southern side of Sutton gap is Mt Pisgah, at the corner of Conesville and Durham townships, which is given as 2885 feet A. T. on the "Durham sheet" of the United States geological survey. For my barometric section I obtained an altitude of 2940 feet A. T., but the readings were probably affected by rain. Guyot gave its altitude, determined by the barometer, as 2905 feet. The accompanying section of the southern side of Mt Pisgah gives the relative position and thickness of the prominent ledges shown on its flank. Not much above the highway on the south side of the mountain are two conspicuous ledges of massive, greenish gray sandstone, the lower one (C^3) 30 feet thick with red sandstone on top, and the upper one (C^5) 15 feet thick above which is red shale. The dip of this sandstone is between $3\frac{1}{2}°$ and 4° S, 30° W. On the *Geologic map of New York* the area of these sandstones is colored as in the Chemung formation and it is probable that they are stratigraphically in the upper part of the zone called Chemung on the Catskill turnpike to the north, though the heavy dip to the south would carry those sandstones rapidly below the altitude which they have on that highway. For the succeeding

a Amer. jour. science, 3d ser. 1893. 45:207.

part of the mountain there are ledges of greenish gray and bluish sandstones alternating with red sandstones and shales, while the red rocks predominate in the upper 450 feet. No fossils were found in any of the outcrops and they certainly agree in lithologic characters and stratigraphic position with the rocks of the Catskill formation.

Eastern townships

The eastern townships of Greene co. from the north to the south are New Baltimore, Coxsackie, Athens and Catskill, while Cairo lies to the south of the western part of Coxsackie and west of Athens. The lines separating the Hamilton and Sherburne and the Sherburne and Oneonta formations have already been described across New Baltimore township and they will now be traced to the south across the county.

Along the Cabin river from Grapeville in the western part of New Baltimore township to Urlton in the western central part of Coxsackie township, there are numerous small, rounded hills composed largely of soil, gravel and boulders, between which are marshy and swampy flats. The rocks are mostly covered by these drift deposits so that it is a difficult region in which to trace the boundaries of geological formations.

LVIII A[1] On the bank of a small brook one fourth mile southeast of Urlton are blue fossiliferous shales in which typical Hamilton fossils are abundant. The fauna is as follows:

1	*Chonetes coronata* (Con.) Hall	(a)
2	*Spirifer mucronatus* (Con.) Bill.	(c)
3	*S. granulosus* (Con.) H. & C.	(rr)
4	*Goniophora hamiltonensis* (Hall) Miller	(r)
5	*Orthonota undulata* Con.	(r)
6	*Nucula bellistriata* (Con.) Hall	(rr)
7	*Nuculites oblongatus* Con.	(rr)
8	*Limoptera obsoleta* Hall	(r)
9	*Actinopteria boydi* (Con.) Hall	(rr)
10	*Tentaculites bellulus* Hall	(rr)

These rocks are indisputably in the Hamilton formation. The dip is $4\frac{1}{2}°$ to the SW, while on the northern point of Coleberg hill

Mt Pisgah of the northern Catskills

to the southeast there is a dip varying from 6° to 9° N, 80° W. The increase of the dip is apparent as one goes eastward toward the folded ridges which become more conspicuous farther south in Athens and Catskill townships. Southeastward the Hamilton formation is found at the summit of the highway where it crosses the northern end of Coleberg hill.

On the hill to the west of the East Branch Potuck and about one mile west of Urlton are green and red shales. The outcrop is on the road toward Result and west of the first road turning north on the western side of the West Branch Potuck. The shales are argillaceous and above them is reddish sandstone. On the *Geologic map of New York* the base of the Oneonta formation is drawn at the three corners west of Result, two and one fourth miles west of this locality. There are other outcrops of the red rocks along this highway to the east of the region mapped as Oneonta, and on the hill to the east of Result is a massive ledge of red sandstone.

LVIII B[1] Two miles south of Urlton the East Branch Potuck and West Branch Potuck unite forming Potuck creek. One fourth mile to the west on the Gayhead road is the Baker flagging stone quarry where a ledge 10 feet thick has been opened. It is a blue sandstone making fair flagging and the flags contain a fair number of specimens of *Spirifer granulosus* (Con.) H. & C., *Camarotoechia congregata* (Con.) H. & C. and *Palaeoneilo constricta* Hall (?). This sandstone ridge is evidently in the Hamilton formation though near its top, for at the four corners three fourths of a mile to the west are red argillaceous shales which continue to the west along the Gayhead road across the northern end of Indian ridge.

To the east of the Potuck creek it is very rocky and rugged, making an extremely poor farming country. The rocks of Potuck hill and the smaller ridges to the west on the eastern side of the creek apparently belong in the Hamilton formation, which in this region is composed mainly of sandstones and coarse, arenaceous shales. From Urlton the top of the formation apparently follows the valley of the East Branch Potuck and

Potuck creek southward to the Catskill creek valley. At the southern end of Potuck creek the rocks dip about 8° W.

In the gorge of the Potuck at the Potuck mill about one mile north of the Catskill creek road are greenish argillaceous shales at the base and in the upper part of the banks are bluish shales and sandstones, some of which show very good examples of ripple marks. No fossils were found though careful search was made for them, and the dip is 8° W. These rocks apparently belong in the Sherburne formation and this conclusion is supported by the presence of red shales 215 feet higher on the steep, eastern side of the southern end of Indian ridge. Red sandstone and shales outcrop at the three corners at the southern end of Indian ridge 145 feet higher than the outcrop mentioned on the eastern slope. On the road down the southern end of the ridge from the above three corners there are several outcrops of red shale, the lowest one only 65 feet above the level of the Catskill creek road. Red argillaceous shales with red sandstone above are shown on the northern bank of the Catskill creek below the place at which the highway turns toward Cairo. The Sherburne formation does not extend much farther up this valley and it is at about this point that the base of the Oneonta formation is represented as crossing the creek on the *Geologic map of New York.*

On the bank of a small brook entering Catskill creek from the south one half mile above South Cairo are red argillaceous shales and sandstones of the Oneonta formation. Above the reds are coarse, gray to bluish sandstones which dip 8° S, 20° E. Farther west toward Cairo a prominent ledge of sandstone, on which glacial striae are nicely shown running a little E of S, crosses the highway. On the southern bank of Catskill creek one and one fourth miles below South Cairo and nearly opposite Potuck creek are green argillaceous shales and sandstones below which is very hard, coarse grained, greenish to reddish sandstone with some red argillaceous shales. The dip is from 3½° to 5° N, 70° W. This variation in the direction of the dip noted at different places along this part of Catskill creek shows that the rocks are gently folded in this region.

Fold on Catskill creek below Leeds. Upper part of anticline Esopus shale, lower part Shaly limestone

LIX A[1] In the highway and railroad cut just above the toll gate one mile above Leeds are blue fossiliferous sandstones and shales. The rocks are greatly indurated and on weathering much stained by iron. The strata show a small roll and the locality is about opposite the western base of Potuck hill. The formation is clearly the Hamilton as is shown by the following fauna:

1	*Tropidoleptus carinatus* (Con.) Hall	(a)
2	*Chonetes coronata* (Con.) Hall	(aa)
3	*Camarotoechia sappho* (Hall) H. & C. (?)	(rr)
4	*Paracyclas lirata* (Con.) Hall	(r)
5	*Nucula bellistriata* (Con.) Hall	(rr)
6	*Prothyris lanceolata* Hall	(rr)
7	*Grammysia* sp.	(rr)

In the Catskill creek above the falls at Leeds and farther up are outcrops of the Onondaga limestone while to the west the Marcellus shale is not exposed, being covered by the deep soil of the creek valley. The precipitous and rocky Vedder hill rises on the western side of the Catskill creek valley to the southwest of Leeds, the rocks of which belong in the Hamilton formation. In fact the exposures in the railroad cut at LIX A[1] are at the northern end of this hill where it is terminated by the Catskill valley, but the hill is really continued on the northern side of the creek by Potuck hill. On the road leading southwest from the toll gate up and along the western slope of Vedder hill the Hamilton fossiliferous shales were seen at an outcrop 70 feet higher than the one in the railroad cut, while at a point 160 feet higher is a ledge of bluish sandstone with some that is coarse grained, grayish, and very hard. Before reaching the summit of the highway, about 215 feet higher than the railroad cut, a ledge of red, argillaceous shale crosses the road which was considered the base of the Oneonta formation.

At the three corners two miles east of Lawrenceville are red shales. In the Bloom quarries in that vicinity the stone is somewhat striped bluish to bluish gray sandstone which splits in thick layers. Between the lower and upper quarry ledges are greenish

to olive argillaceous shales in which no fossils were found. The Bloom and other quarries on the hillside east of Lawrenceville have massive sandstones, bluish gray in color, banded with lines of a slightly different shade, which do not split into thin, flagging stones but into thicker layers. These stones are harder than the Hamilton flags and they are cut into blocks for paving. No fossils were found in them and since olive argillaceous shales are interstratified with the sandstones they are referred to the Sherburne formation. At the place where the Lawrenceville road crosses the small brook which is followed down the eastern side of this ridge into the Kaaterskill creek valley are typical blue Hamilton shales containing characteristic fossils.

1	*Spirifer granulosus* (Con.) Hall	(rr)
2	*Palaeoneilo constricta* Hall	(rr)
3	*Grammysia alveata* (Con.) Hall	(rr)
4	*Schizodus appressus* (Con.) Hall	(rr)
5	*Elymella nuculoides* Hall	(rr)
6	*Pleurotomaria sulcomarginata* Con.	(r)
7	*Bellerophon lyra* Hall	(rr)
8	*Spirophyton velum* Van.	(rr)

This outcrop is some 300 feet higher than the Kaaterskill creek which flows northeasterly for five and one half miles at the eastern base of this steep ridge. The greater part of the Kaaterskill valley for this portion of its course has been cut out of the comparatively soft Marcellus shales which are shown on the eastern bank south of the bridge on the road from Catskill through Kiskatom to Palenville. The western side of the ridge to the east of the creek is composed of the Onondaga limestone, the distribution of which is well shown on Prof. Davis's map of "The folded Helderberg limestones in Greene county, N. Y."[a]

The rocks to the west of this bridge forming the first terrace are no. 132 of Mather's section from Catskill mountain to the Kaaterskill creek which he described as " Dark shales and shaly grits and flags, of several hundred feet in thickness, embracing

a Bulletin Museum comparative zoology, v. 7, Geol. series, v. 1, no. 9, 1883, pl. 13.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from the Ithaca group to the Marcellus shales."[a] In another place he states that "This part of the series can be examined satisfactorily only by following up the bed of a stream near which the turnpike passes. These strata are probably 1000 feet in thickness."[b]

On the roads to the west of Kiskatom are numerous outcrops of red shales and some sandstones. On the road to the south leading down into the Kaaterskill valley are massive, hard sandstones with banded structure which are in the Sherburne formation. In a small quarry some 35 feet lower are massive sandstones which split into thick layers. Plenty of plant stems were found in these rocks but no other fossils. The dip is 8° N 60° W. At the three corners of the road a little lower than the quarry are blue shales containing Hamilton fossils, consequently it appears that the sandstones in the quarry are near the dividing line between the Hamilton and Sherburne formations.

LX A[1 and 2] At the High falls[c] on the Kaaterskill creek not far from the Greene and Ulster county line is a deep and rocky gorge in which the upper Hamilton rocks are finely shown. Below the massive sandstone stratum which forms the bed of the creek above the falls are rather fine, blue argillaceous shales (A^1) which contain a fair Hamilton fauna of the species usually found in the fine shales of that formation. The following species were collected from these shales:

1	*Tropidoleptus carinatus* (Con.) Hall	(c)
2	*Chonetes coronata* (Con.) Hall	(c)
3	*C. lepida* Hall	(rr)
4	*C. setigera* Hall	(r)
5	*Strophalosia truncata* (Hall) Beecher (?) Imperfectly preserved.	(rr)
6	*Spirifer mucronatus* (Con.) Bill.	(rr)
7	*S. granulosus* (Con.) H. & C.	(c)
8	*Stropheodonta perplana* (Con.) Hall	(rr)

a Geology of New York. 1843. P. 1, p. 305.
b Ibid., p. 306.
c Also called "Great falls."

9 *Palaeoneilo emarginata* (Con.) Hall (rr)
10 *P. constricta* (Con.) Hall (c)
11 *Nucula bellistriata* (Con.) Hall (r)
12 *N. varicosa* Hall (rr)
13 *Nuculites triqueter* Con. (rr)
14 *Paracyclas lirata* (Con.) Hall (c)
15 *Orthonota* (?) *parvula* Hall (rr)
16 *Modiella pygmea* (Con.) Hall. (rr)
17 *Sphenotus truncatus* (Con.) Hall (rr)
18 *Nuculites oblongatus* Con. (rr)
19 *Solen* (*Palaeosolen*) *siliquoidea* Hall (?) (rr)
20 *Prothyris lanceolata* Hall (rr)
21 *Grammysia constricta* Hall (rr)
22 *Schizodus appressus* (Con.) Hall (rr)
23 *Microdon* (*Cypricardella*) *tenuistriatus* Hall (rr)
24 *Liopteria dekayi* Hall (c)
25 *Orthoceras subulatum* Hall (?) (r)
26 *O. crotalum* Hall (?) (rr)
27 *Pleurotomaria sulcomarginata* Con. (?) (r)
28 *Bellerophon* sp. (rr)
Fragments.
29 *Dignomia alveata* Hall (?) (rr)
30 *Lingula* sp. (Broken) (rr)
31 Crinoid stem (Large) (rr)

Some 35 feet of these blue shales are shown at the falls and the dip below the falls is from 10½° to 11½° due west.

Forming the brink of the falls and the bed of the creek above them is a heavy sandstone (A^2) between three and four feet in thickness, which splits in irregular layers. The upper part of this sandstone contains an abundance of the species usually found in the coarser Hamilton deposits as for example:

1 *Spirifer granulosus* (Con.) H. & C.
2 *S. mucronatus* (Con.) Bill.
3 *S. audaculus* (Con.) Whitf.
4 *Tropidoleptus carinatus* (Con.) Hall

Plate 19

KAATERSKILL FALLS. CATSKILL

5 *Chonetes coronata* (Con. Hall
6 *Strophoedonta perplana* Con. (?)
7 *Grammysia bisulcata* (Con.) Hall
8 *Spirophyton* sp. etc.

The dip above the falls is 10½° N. 60° W. The western bank of the creek above the falls is composed of alternating strata of shales and sandstones forming a perpendicular cliff 85 feet in hight. It was not possible to determine whether the Hamilton fauna continues to the top of the cliff or not. The fossiliferous nature of these rocks was noted by Prof. Davis who wrote that "several strata are very fossiliferous, *Spirifer mucronata* and *medialis* are both of common occurrence;"[a] while Prosser has in earlier papers partially listed the fossils of this locality.[b]

On the hill one half a mile west of High falls and 130 feet higher than its top is the small stone quarry of Hugh Smith. The rock is bluish gray, rather coarse grained sandstone which has bands of color, some of it with a slightly reddish tint in the bright sunshine. The sandstone is capped by a mass of green, argillaceous shales with some layers of bluish color. No fossils were found and it is this part of these rocks which I have referred to the Sherburne formation. The soil in this vicinity is reddish from the leaching of the higher red shales. The first reds seen in place however are at the three corners, three fourths of a mile farther northwest on the ridge east of the Kaaterskill. This locality is just south of the Greene and Ulster county line about one and one half miles east of Palenville. Some of the red shales are very arenaceous and it is quite probable that the base of them is somewhat farther east, but covered by drift and soil along the highway. Red shales show at various places along this ridge and the highway to the south of Saxton in Saugerties township, Ulster co.

On the geological map accompanying this report the lines separating the Hamilton and Sherburne formations and the Sherburne and Oneonta are indicated as nearly as we could follow

a Bull. Mus. comp. zoology, v. 7, Geol. ser. 1883, 1: 318.
b American geologist, 1891, 7: 365; Bulletin United States geol. survey, no. 120, 1894, p. 69.

them across this county. It is a difficult region to map and in places the indicated lines are probably only an approximation. In the above account the localities at which the outcrops near the dividing lines occur have been described so fully that it is not deemed necessary to define the course of these lines and all interested in their position may follow them readily on the geological map.

Greene county Catskills

The western and central portions of Greene county are in the Catskill mountain region, the rocks of the greater part belonging in the Catskill formation for which it is the typical region of the "Catskill division" as they were called by Mather. His detailed section "from the top of the South mountain near the Mountain house on the Catskills, down to the Helderberg division at the Kaaterskill creek,"[a] gave the rocks of the Catskill and Erie divisions[b] and extended from the eastern part of Hunter northeasterly across the southern part of Catskill township to the Kaaterskill creek.

In 1874 Mr Andrew Sherwood measured very accurately a section of these rocks beginning in the Kaaterskill creek at Palenville, following the famous Kaaterskill clove and continuing to the top of Round Top mountain to the south of the clove[c].

Sherwood's total thickness for the rocks from the upper part of Palenville to the top of Round Top is 3482 feet, while Prof. Hall estimated the thickness of all the rocks from the top of the Hamilton formation to the summit of Round Top as 5800 feet.[d] Sherwood gave accurately the lithologic characters and thickness of the various strata so that there is no need for another detailed account of this typical Catskill section. Sherwood correlated the red and green shales (no. 94 of his section) in the

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a Geology of New York. 1843. P. 1, p. 302–5.

b "The Erie division in the first geological district consists of the following groups:
1 Ithaca and Chemung group
2 Hamilton group
3 Marcellus shales." Ibid., p. 317.

c Proc. Amer. philosophical society, 1878, 17: 346-47. This section was also republished by Ashburner in the Second geological survey of Pennsylvania, F. 1878, p. 218–19, while Prof. James Hall has given an account of it in the 28th Report N. Y. state museum of natural history, 1879, p. 14–15.

d Proc. Am. ass'n adv. science. 24: 82, 83.

Plate 20

Stony clove, the pass between Hunter and Plateau mountains

Kaaterskill creek above the bridge opposite the hotel in the upper end of the village, with the red shaly rock (no. 12) at the top of the Manorkill cataracts near Strykersville. The author did not see any evidence to support this exact correlation of these two sections, nor did Sherwood give any reason for his correlation. But few fossils have been found in the rocks, the animal remains in which are bones and plates of fish that were first discovered by Sherwood, and on account of their presence in considerable abundance in three layers (nos. 105, 107 and 111) in the lower part of the clove he termed them "fish-bone beds." The lower bed is in a greenish, shaly rock which is quite hard, and there are numerous fragments of fish bones and plates most of which are badly broken. The second bed is in a mottled red and green argillaceous and rather soft shale. The bed of no. 111 is near the bottom of a mass of red shale, 103 feet in thickness according to Sherwood, where fragments of fish scales were seen, but they are not nearly so abundant as in the two lower beds. These specimens were not identified, so far as known to the writer, except that Prof. Hall referred to these beds, stating that they were "charged with the remains of *Holoptychius*."[a] Additional specimens were collected by the writer which have been studied by C. R. Eastman, who identified *Dinichthys* sp. and *Sauripteris Taylori* Hall. (*See* Dr Eastman's description of these specimens at the close of this report.)

In addition to the fish remains the author found numerous specimens of *Psilophyton princeps* Dn. in a bluish gray arenaceous layer at the foot of the Cascades below Haines's falls, about 400 feet below the base of the heavy conglomerate which is well exposed in Twilight park on the southern side of the clove.[b]

The massive conglomerate ledge in Twilight park occurs at an elevation of about 2000 feet A. T. About 15 feet containing large white and pinkish quartz pebbles are shown on the driveway. Several conglomerates are mentioned near this part of Sherwood's section and I am uncertain which one the Twilight

a 28th Report N. Y. state museum natural history, p. 14.
b Amer. geol. 1891. 7:365, and Bulletin United States geol. survey, no. 120, p. 67.

park conglomerate represents. Above the conglomerate along the path up High peak for the first 800 feet the rocks are mostly covered, but then ledges of coarse, greenish gray sandstone with some red sandstone occur occasionally. There are in places indications of red shales, but the softer rocks are pretty well concealed. Toward the summit of the mountain, which is 3660 feet A. T., the sandstone is coarser, not so firmly compacted and weathers to a light gray color. Pebbles are not infrequent though not sufficiently abundant to make a conglomerate. This is supposed to represent the "coarse gray sandstone" of Sherwood's section, which he gave as 440 feet in thickness forming the top of Round Top and which Ashburner referred to the Pocono formation.[a]

The Kaaterskill creek, which has cut the deep chasm known as the Kaaterskill clove, receives from the north Lake brook, the outlet of North and South lake, two small lakes west of the crest of the mountains, one north and the other west of the Catskill Mountain house. On this brook near the head of the gorge a little below the Laurel house are the Kaaterskill falls which were the subject of Bryant's beautiful poem. The accompanying plate gives a fair idea of these falls which taken together are said to be 260 feet high. On the main creek at the head of the clove is another high cascade known as Haines's falls, the geological structure of which was described by the writer several years ago,[b] a winter view of which was given. About three fourths of a mile west of Haines's falls is the divide between one branch of the Kaaterskill creek and one of the head branches of the Schoharie river.

Hunter, a very mountainous township, crossed diagonally from the southeast toward the northwest by the head waters of the Schoharie river, is the great Catskill resort for summer tourists. The rocks are all of the Catskill formation unless the tops of the mountain peaks are composed of the Pocono formation of the Lower Carboniferous as is claimed by some geologists. They

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a Second geol. survey Penn. F. p. 218-19.

b Bull. United States geol. survey, no. 120, p. 66-67.

Plate 21

Colonel's chair, south of Hunter

contain no fossils, so far as known, except a few plant remains and an occasional plate or bone of a fish, while lithologically they consist of beds of gray sandstone, green shales and some conglomerates alternating very persistently with red shales and sandstones. As details would be monotonously similar it is not considered advisable to go into any description of the very large number of sections that might easily be constructed in this region.

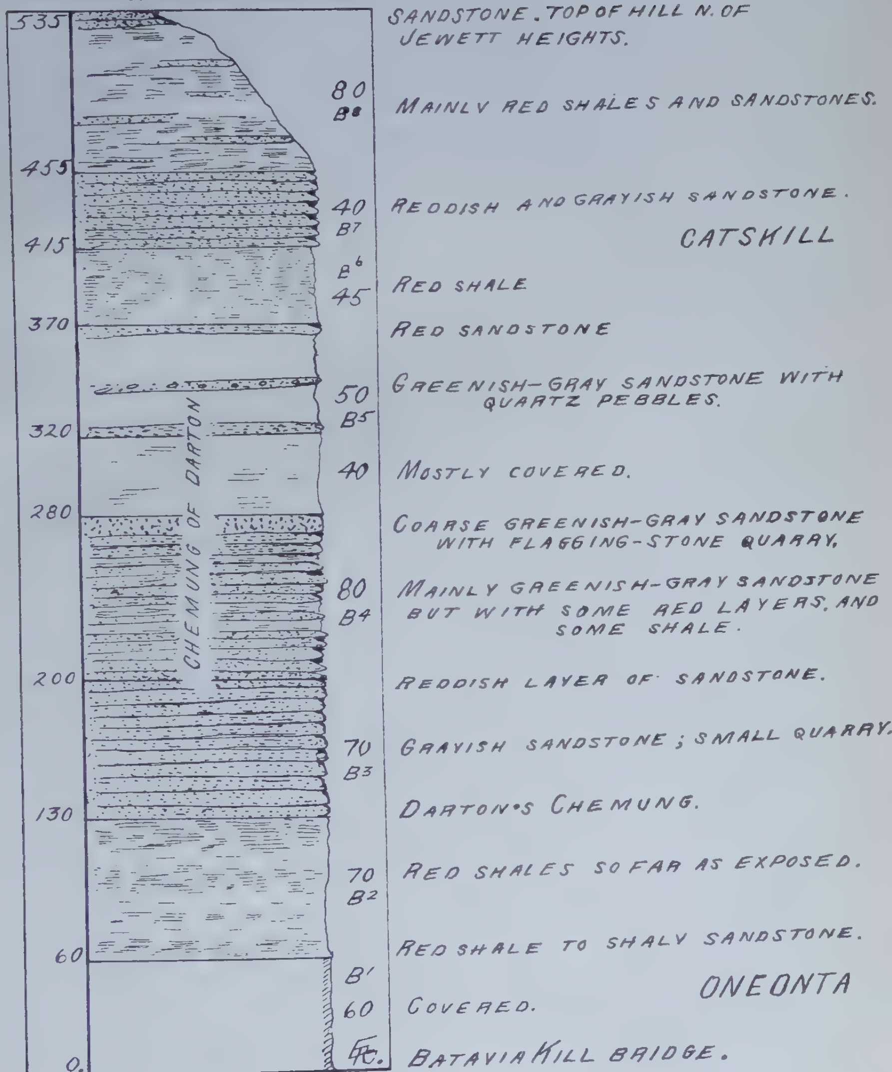
In the Catskill mountain region there are a number of deep and narrow passes between the mountains, one of the most famous being the Stony clove in the western part of Hunter township between Hunter and Plateau mountains. For some distance the bottom of the clove is very narrow with only room enough for the highway and the track of the Stony clove and Catskill mountain railway. The slope of Mt Hunter on the west is very steep, its peak the highest of the Greene co. Catskills, 4025 feet A. T., being only about one and a half miles to the northwest. Both slopes are densely wooded so that the clove for the greater part of the day is in the shade, while a breeze continually passes through it, making a delightful resort on a hot summer day. The view shows the northern end of the clove with Mt Hunter on the right and Plateau mountain on the left. To the south of Hunter village and the Schoharie river is a prominent mountain known as the Colonel's Chair, the highest part of which is 3165 feet A. T. There are steep sandstone ledges at the northern end of the mountain facing eastward, the top of which are grayish, coarse grained sandstones that are not very hard, giving the upper part of the mountain something the shape of a chair. These nearly perpendicular ledges on one side of the mountain peak are quite well shown in the accompanying picture.

In the Catskill mountain region of the western part of Greene co. the principal study was given to that portion which is colored on the *Geologic map of New York* as in the Chemung formation. In the Schoharie river valley the Chemung is represented as beginning at the upper end of Lexington village and continuing for about two miles down the valley. On the south bank of

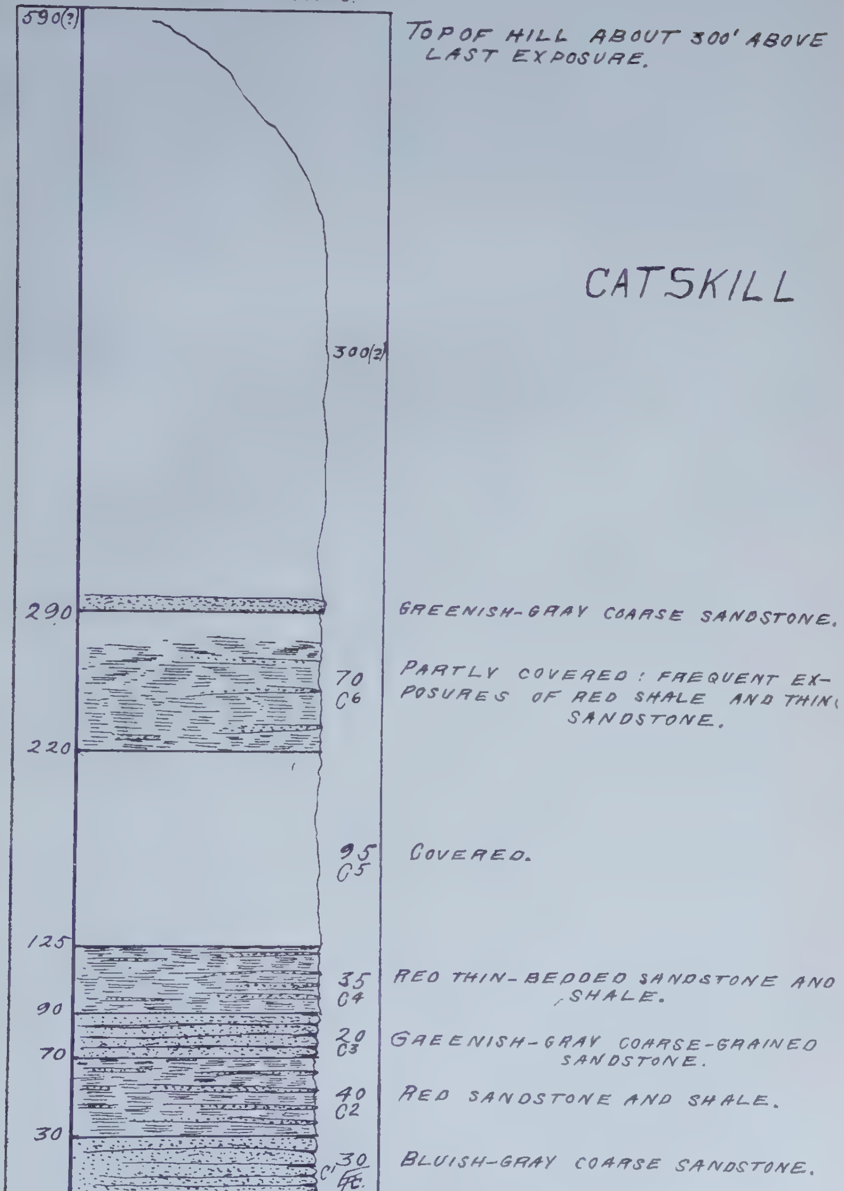
the Schoharie just above Lexington is a cliff of shaly red sandstone 20 feet high. Below the village on the northern bank are coarse greenish gray sandstones which contain some pebbles. The dip at this locality is S, 70°W. On the northern side of the road some distance below Lexington are massive ledges of sandstone. At the base it is gray and shaly but becomes thick bedded above, forming a very prominent ledge of bluish to greenish gray, coarse grained sandstone. Between the two massive strata of greenish gray sandstone are red shales and reddish sandstone. No fossils were found at these exposures or any characters to distinguish them from the Catskill rocks farther up the river. Again by the side of the road and the Westkill to the southwest of Lexington near the upper part of the area mapped as Chemung, are ledges of coarse grained, heavy bedded, greenish gray sandstone. No fossils were found. Farther south in the western part of the township is a deep clove through the Westkill range, at the divide between a branch of the Westkill on the north and another of the Esopus creek on the south, known as Deep hollow at the head of the Bushnellville clove. In the hollow the dip of the heavy gray sandstone is about 4°W. The view of this clove is from the low hill not far north of Westkill village.

LXI B. This is a section through the so-called Chemung of the Jewett range on the southern side of the Bataviakill beginning at the creek level about two miles above Ashland and following the line of the highway to the top of the hill north of Jewett hights. On the accompanying plate the lithological characters of the rocks are given so fully that it is hardly necessary to describe them at any length in this part of the report. In the lower part of B^3 is a small quarry in bluish gray to greenish gray, rather coarse grained sandstone with greenish and bluish argillaceous shales. Some of the shaly layers contain fragments of plants and in the upper part of the quarry the layers have very irregular bedding. The dip is 1° to 1°+ S, 80° W. This gray sandstone is apparently at the base of the rocks colored as of Chemung age on the *Geologic map of New York*. Succeeding

No. 61, B. SECTION OF HILL SOUTH OF BATAVIA KILL TWO MILES ABOVE ASHLAND



No. 61, C. SECTION OF HILL BETWEEN HENSONVILLE & WINDHAM THROUGH DARTON'S CHEMUNG.



65 to 70 feet of these grayish sandstones there is a stratum of reddish sandstone which is followed by from 80 to 85 feet of mostly greenish gray, coarse grained sandstone (B^4) the layers of which are rather more massive than those of B^3. Interstratified with these greenish sandstones are layers of reddish sandstone and shale a few feet in thickness. Near the top of B^4 is a small flagging stone quarry, the flags of which are from one to two inches thick, coarse grained and decidedly greenish gray in color. In places the layers are very much crossbedded. The dip noted is from 4° to 4°+ S, 30° W and 2° N, 60° W. At B^5 are heavy ledges of coarse, greenish gray sandstone, very coarse grained near the middle of the ledge, with large quartz pebbles and at the top is red sandstone. On the old road near Jewett hights, which are 1810 feet A. T., are glacial striae running north and south. On the hill to the northeast of Jewett hights the rocks are mainly red sandstones and shales, and this region was represented on the *Geologic map of New York* as near the base of the Catskill formation as well as Jewett hights and the hill to the northwest.

LXI C. Another section about four miles east of LXI B was examined across the belt of country mapped as Chemung from Hensonville to Windham in the upper part of the Bataviakill valley. This section is here reproduced and as will be readily seen the rocks are not nearly as well shown as on the section south of Ashland. The lower part of the section is on the lower part of the hill to the south of Windham and the Bataviakill which is represented on the *Geologic map of New York* as in the lower part of the Chemung. It will be noticed that the rocks consist of bluish gray and greenish gray, coarse grained sandstones alternating with red sandstones and shales. The base of these rocks is somewhat above the highway and they have a thickness of 125 feet. Then for 95 feet the rocks are covered, succeeding which for 70 feet the slope is partly covered but has frequent outcrops of red shales and thin sandstones. No fossils were found on this hillside. On top of the hill southwest of Hensonville is a small flagstone quarry in coarse grained, green-

ish gray sandstone. This is a typical Catskill sandstone and is in the area represented as near the base of that formation on the *Geologic map of New York.* There is a slight syncline in the quarry for at the northeast end the dip is 1° S, 40° W, while at the other end it is about 1° in the opposite direction. Ledges farther up the highway show a dip of 1° N, 30° E.

After an examination of the area mapped as Chemung on the *Geologic map of New York* to the west of Durham, near Windham, south of Ashland, near Lexington, south of the Manorkill and in Roxbury it does not appear to the writer that, with the exception of the reported discovery of *Spirifer disjunctus* Sow. west of Durham, there is any proof of its Chemung age. The lithologic character of the rocks is not different from that of the Oneonta formation below or the Catskill above, and with the absence of fossils it appears very difficult if not impossible to correlate this zone with the Chemung. It is true that a part of the Catskill formation of eastern New York is synchronous with the Chemung of southern and western New York; but with merely the alternation of reds and grays in eastern New York it does not seem possible to the writer to divide the mass of rocks into distinct formations which can be traced and mapped for any distance. It seems better to leave it as one formation under the name Catskill, not failing to recognize that in time it is nearly equivalent to the rocks called Portage and Chemung in western New York. The exceptions are at the base of the Catskill, or Oneonta formation as we have still called the lower part of this mass of rocks in Greene co., which probably does not reach as low as the base of the Portage in western New York, and at its top which is probably of later age than any of the Chemung in southwestern New York or northwestern Pennsylvania.

ULSTER COUNTY

This county which lies directly south of Greene co. extends from the Hudson river on the east to Delaware and Sullivan counties on the west. The northwestern part of the county is very mountainous, in which region the Catskills reach their cul-

mination in Slide mountain, 4205 feet A. T. The two principal streams are Esopus creek which flows southeasterly across the northern part of the county till near Kingston when it turns northerly for several miles, finally breaking through the limestone ridge near Saugerties where it enters the Hudson. The second stream, Rondout creek, flows northeasterly across the southeastern part of the county and enters the Hudson river at Rondout. Farther east is the Walkill, a southern tributary of the Rondout, and between these two valleys is the precipitous Shawangunk mountain, which extends southwesterly, from the vicinity of Rosendale across this and Orange co., whence it may be traced across northwestern New Jersey into Pennsylvania where it is known as Kittatinny mountain. The structure of the Ulster co. part of this mountain has been well described by Mr N. H. Darton.[a]

Distribution of the middle and upper Devonian

The strike of the Silurian and Devonian formations across Greene co. and the northern part of Ulster to Kingston is ssw; where the direction changes to sw across the remaining parts of Ulster, Sullivan and Orange counties into New Jersey and Pennsylvania. The Hamilton, Sherburne and base of the Oneonta formations, or Catskill as it is generally called in this part of the state, cross in Ulster co. the townships of Saugerties, Kingston, Woodstock, Hurley, Olive, Marbletown, Rochester and Wawarsing from the north to the southwest.

On the *Geologic map of New York* the Oneonta formation is not represented any farther south than the Palenville region along the Greene and Ulster county line, the lower portion of the alternating red and gray rocks to the southwest of this region being included in the Catskill formation. Mr Darton has said "I have not traced the formations [Oneonta and Chemung?] farther southward than Palenville along the eastern front of the Catskills but there can be no doubt as to their extension across the

[a] National geographic magazine, 1894, p 6:23; and the 13th an. rep't N. Y. state geologist p. 346.

Delaware and far into Pennsylvania."[a] There is no question but that the lower reds and grays of Ulster co. and farther southwest are synchronous with the rocks of Greene and Albany counties which are called Oneonta, but as there is no line of separation which can be traced between the lower and middle rocks of this mass it seems as well to the author to class them together as one formation, to which would be applied the name Catskill in the sense in which it was used by Mather for this region. In fact I am inclined to think that the above arrangement would be a better classification for this mass of rocks in Greene, Albany and southeastern Schoharie county than the plan of representation followed on the *Geologic map of New York.* The above usage apparently agrees with that suggested by Prof. H. S. Williams for the term Catskill in eastern New York for he said, "It is an appropriate local formation name for deposits succeeding Hamilton or Chemung formations in eastern New York and farther southwest... The Catskill is a distinct and well defined geological formation, but it is not a period or an epoch, nor does it represent any particular period of geological time."[b]

Under the eastern townships of Greene co. the upper Hamilton, Sherburne, and lower reds were traced from Catskill township across the county line into Saugerties township, consequently at this locality we will begin the consideration of the limits of these formations toward the southwest. The banded sandstone found in the small quarry to the west of High falls on the Kaaterskill may be followed along the highway to the ssw to the three corners one half mile northwest of Quarryville. There is a quarry to the west of the turn and another to the east, both of which contain the banded hard sandstones. In the western one there are coarse, greenish shales below the sandstones, while some of the sandstones in the more eastern quarry have a slightly reddish tint. No fossils were found and the rocks are apparently in the Sherburne formation. The large quarries in Quarryville contain coarse, thick bedded, bluish gray sandstones with shale

a Amer. jour. science, 3d ser. 1893, 45:207.
b Jour. geology, 1894, 2:153-54.

partings. No fossils, except fragments of plants, were found and the rocks seem to be in the lower part of the Sherburne. The dip is between 6° and 7° NW. A picture of the principal flagstone ledge in Quarryville appears on plate 23 of the *13th annual report of the New York state geologist.* By the side of the highway in the eastern part of the village at the beginning of the descent are Hamilton shales with their typical fossils. The ridge to the north of Quarryville is very rough and rocky and the rocks along the quarry road leading to its summit one and one half miles north of the village are greenish and bluish argillaceous shales interstratified with the coarse banded sandstone, all apparently in the Sherburne formation. Red shales occur along the highway about one and one fourth miles northwest of Quarryville toward Saxton. To the west of south in the Plaaterskill valley the base of the red rocks soon crosses to the western side of the creek and from Fawns south to the first road for Woodstock, near where the creek turns to the southeast, there are frequent outcrops of red shales on the western side of the creek while none were seen on the eastern side.

About two miles west of Fawns at West Saugerties is the foot of the Plaaterskill clove, a deep gorge cut by the Plaaterskill through the eastern escarpment of the Catskills. This gorge is four miles south of the Kaaterskill clove with which it is parallel and its greater part is in the southeastern corner of Hunter township, Greene co. These two cloves are the only deep gorges which have been cut in the eastern face of the Greene co. Catskills. By the side of the clove road about 400 feet below the head of the clove is a stone quarry of bluish to greenish coarse grained sandstone. The dip at this locality is between 6° and 7° N, 40° W. The rocks along the upper part of the clove road are coarse, greenish gray sandstones alternating with reddish sandstones and shales and bluish argillaceous shales, all of which are typical Catskill rocks. Near the head of the clove is a flagstone quarry in greenish gray, coarse grained sandstone, while some of the layers contain large quartz and other pebbles.

On the ridge east of Fawns and the Plaaterskill are fairly coarse grained, bluish gray sandstones probably in the Sherburne formation. Farther southeast the country is very wild and rough having been cleared and now covered by the second growth of trees, with here and there a stone quarry but no farming land. In fact for many miles along this ridge from the northern part of Ulster co. to the southwest the country is nearly a wilderness. In this region at the four corners on the road from Fawns to Saugerties are a number of stone quarries. Just west of the corners is an extensive quarry in bluish, massive, somewhat banded sandstone with a thickness of six and one half feet. Above are eight feet of bluish shales and then five feet of shattered sandstone. Dip is $2\frac{1}{2}°$ S, 30° W, and there is also a heavy dip to the west. No fossils were found in the sandstone or shale and this quarry is considered as at about the base of the Sherburne formation. On the road just east of the corners are bluish black, arenaceous shales, layers of which contain *Spirifer granulosus* (Con.) H. & C. and other fossils, so that these rocks are clearly in the Hamilton formation. The line of separation between the Sherburne and Hamilton formations at this locality is about on the line of the north and south highway. It is only about one mile farther east to the eastern face of the line of hills which form the western boundary of the Hudson valley. The range is broken by streams and at places rises into points like Mt Airy and Mt Marion from 500 to 700 feet A. T. To the east in the valley is the Onondaga limestone, in the lower part of the steep ridge are fine, black Marcellus shales, while the upper part, and for some distance westward, belongs in the Hamilton formation. In general in all this region there is a heavy westerly dip with a lighter one to the south. The rocks consist of alternating masses of massive sandstone and argillaceous or arenaceous shales. The sandstones form steep cliffs which are numerous and very conspicuous in passing from the east toward the west. On account of the heavy westerly dip all sandstone slopes rapidly toward the west. For some distance along the highway or in the fields the top of it frequently shows, with a small stream or

marsh at its western edge beyond which rises another sharp ridge.

Near the church in Unionville or Centreville, about one mile southwest of the four corners on the road from Fawns to Saugerties, are coarse, bluish rather arenaceous shales containing large Hamilton lamellibranchs. The fossils occur in layers and are not abundant as will be seen from the following list:

1	*Modiomorpha mytiloides* Con.	(r)
2	*M. macilenta* (?) Hall	(rr)
3	*Mytilarca oviformis* (Con.) Hall	(r)
4	*Camarotoechia* sp.	(rr)
5	*Sphenotus subtortuosus* (?) Hall	(rr)

Along the highway to the east are sandstones and shales in which fossils are very rare. The quarries at this place are located both below and above the zone in which the fossils were found. The sandstones in these quarries do not have the marked banded appearance of those in the Sherburne formation and this fact together with the occurrence of Hamilton fossils seems to show that they are in that formation. The line of division between the Hamilton and Sherburne is given on the map as not far west of Unionville, while the Plaaterskill valley to the west is in the Sherburne formation. At the corners west of the Plaaterskill on the road from Unionville to Daisy is a small church and along the road from the church south to the east and west road from High woods to Daisy are frequent outcrops of red and green shales and gray sandstones. The base of the reds is apparently to the east of this road.

In the quarry at Highwoods is a bluish, somewhat banded sandstone which is separated by some bluish though mainly greenish layers of argillaceous shales. There is a stratum of breccia and some of the sandstone has quite a reddish tint in the bright sunshine. No fossils were found. The rock is referred to the Sherburne formation. In this region there are excellent examples of glacial planed and striated surfaces, east of the Highwoods store for example on blue sandstone by the side of the road are conspicuous striae which run N 15° E. In old quarries

of bluish banded sandstone east of Highwoods four corners are bluish banded sandstones and green shales. The sandstone is heavy bedded and does not split readily into thin flags. No fossils except plant stems were seen and the rocks are in the Sherburne. Glacial striae occur running S, 10° W, and N, 10° E. The dip varies from about 5° S, 50° W, to 4° N, 40° W. The westerly dip is apparently more irregular than the southerly, due partly to the irregular nature of the strata.

On the highway not far west of the Plaaterskill and just below the house of Mr C. Plass are bluish, rather arenaceous shales which contain some fossils as *Paracyclas lirata* (Con.) Hall, *Spirifer* and a few other species. This locality is surely in the Hamilton and probably the top of the formation is farther west, since coarse, bluish arenaceous shales, with a slightly concretionary structure, containing fragments of fossils were noticed along the highway to the west of this house. About one fourth mile southeast of the Plass house the highway crosses the Plaaterskill to the west of the Mt Marion station. At this locality on the western bank of the creek is a cliff about 100 feet high composed of the fine, somewhat arenaceous, Hamilton, blue shales. There are occasional layers of somewhat coarser structure which frequently contain numerous specimens of *Spirifers*. The blue shales do not contain fossils abundantly though they are fairly common. The species are typical Hamilton ones and this is an excellent locality for studying the Lower Hamilton of this region. The following species were found in these shales as the result of one hour's search:

1	*Bellerophon* sp.	(rr)
2	*Nyassa arguta* Hall	(rr)
3	*N.* *recta* Hall	(rr)
4	*Orthonota parvula* Hall	(r)
5	*Paracyclas lirata* (Con.) Hall	(r)
6	*Spirifer granulosus* Hall	(a)
7	*S.* *mucronatus* (Con.) Bill.	(r)
8	*Orthis impressa* Hall	(r)
9	*Chonetes scitula* Hall	(r)

10	*C. setigera* Hall	(r)
11	*C. coronata* (Con.) Hall	(rr)
12	*Pleurotomaria rotalia* Hall (?)	(rr)
13	*Orthoceras* sp.	(rr)
14	*Palaeoncilo plana* Hall	(rr)
15	*Nuculites oblongatus* (Con.) Hall	(rr)
16	*N. triqueter* Con.	(rr)
17	*Nucula corbuliformis* Hall	(r)
18	*N. bellistriatus* (Con.) Hall	(r)
19	Plant stems	(rr)
20	*Modiomorpha concentrica* (Con.) Hall	(r)
21	*Grammysia* sp.	(rr)
22	*Dignomia alveolata* (Hall) H. & C.	(rr)
23	*Lingula densa* Hall	(r)

To the southwest of Dutch Settlement (Ruby p. o.) in the northern part of Kingston township is a large quarry of flagging stone. The color is bluish to bluish gray, some of which is faintly banded, forming a ledge five feet thick that is worked. Part of the ledge splits into thin even layers from two to three inches thick which make excellent flagstone, while the thicker layers make building stone. The same layers do not split as readily when followed from the flagstone part of the quarry. The dip is between 4° and 5° S. 60° W. Above the sandstone are argillaceous shales of decidedly greenish color. The sandstone is similar to the so-called Hamilton blue flagstone, but it is probably in the Sherburne formation.

Farther south in a wild and rugged region is the Sawkill valley along which are numerous flagstone quarries, specially in the vicinity of Jockey hill, in the Hamilton formation, and its top crosses the valley about two and one half miles above the village, while the base of the reds is found not far above the Sawkill reservoir more than three miles east of north of West Hurley. Kingston, Hurley and Olive townships are crossed by the Ulster and Delaware railroad and the section along this railroad was described by the writer several years ago,[a] before the Sherburne

[a] Bull. United States geol. survey, no. 120, p. 51-65.

formation had been traced into eastern New York so that there is no mention of that formation though it was stated in reference to the "Hudson river bluestone" quarries that "stratigraphically the lower portion of these quarries belongs in the Hamilton and the upper part of the belt in the Portage."[a] In the long railroad cut one half a mile east of West Hurley are thick and thin bedded sandstones alternating with bluish, fine argillaceous and greenish blocky shales. In places the cut is from 25 to 30 feet in depth and the rocks are shown on the highway below the railroad. The dip in places varies from 2½° to 3½° S, 45° W. Fragments of plants were the only fossils found and the cut seems to be in the Sherburne formation. On the highway just below the Bristol hill church and only a short distance west of Stony Hollow are blue, arenaceous, blocky shales which contain a few Hamilton fossils. At the eastern end of the first railroad cut west of Bristol church, are fine blue shales, in which Hamilton fossils are abundant. The rocks at Bristol church are clearly in the Hamilton formation and the following fauna was obtained from the railroad cut:

1	*Chonetes coronata* (Con.) Hall 85 specimens.	(aa)
2	*Nyassa arguta* Hall 40 specimens.	(aa)
3	*Nuculites oblongatus* Con.	(rr)
4	*Prothyris lanceolata* Hall	(rr)
5	*P. planulata* Hall	(rr)
6	*Paracyclas lirata* (Con.) Hall	(c)
7	*Orthonota* (?) *parvula* Hall	(rr)
8	*Microdon* (*Cypricardella*) *complanatus* Hall	(r)
9	*Tropidoleptus carinatus* (Con.) Hall	(rr)
10	*Cyrtina hamiltonensis* Hall	(r)
11	*Spirifer mucronatus* (Con.) Bill.	(rr)
12	*S. ziczac* Hall	(c)
13	*Streptorhynchus chemungensis* (Con.) Hall 43 specimens.	(aa)

[a] Bull. United States geol. survey, no. 120, p. 55.

Plate 22

WEST OF WEST HURLEY; CROSSBEDDING

14 *Orthis* (a)

Some of the specimens resemble *O. vanuxemi* Hall but others are nearer *O. penelope* Hall.

15 *Palaeoneilo constricta* (Con.) Hall (rr)

16 *P. maxima* (Con.) Hall (rr)

17 *Sphenotus truncatus* (Con.) Hall (c)

18 *Dalmanites boothi* (Green) Hall (r)

19 *Schizodus appressus* (Con.) Hall (?) (rr)

20 *Actinopteria boydi* (Con.) Hall (a)

25 specimens.

21 *Glyptodesma erectum* (Con.) Hall (rr)

22 *Discina* sp. (rr)

On the hill to the northeast of Bristol church the rocks are all coarse sandstones alternating with shales, and belong apparently in the Sherburne formation. It seems that the quarries in the immediate vicinity of West Hurley are in the Sherburne formation, while the older ones near Bristol church and toward Stony Hollow are in the Hamilton. Mr Darton called these sandstones the "Lower flag series" in his *Preliminary report on the geology of Ulster county*, and stated that "the age of the series is not definitely known, but it is in the main of the upper Hamilton group; the shales and some of the sandstone beds contain fossils, but these have not yet been studied."[a]

On the *Geologic map of New York* the base of the Catskill is represented as north of the railroad and Olive branch to the west of West Hurley. Red shales and sandstone however occur on the highway south of the railroad not far west of West Hurley and there are a number of excellent exposures of the red rocks on the highway between this point and the stone church about four and one half miles west of West Hurley. On the north side of the highway about two and one half miles from West Hurley is a prominent ledge of crossbedded, gray sandstone which rests on red shale. There is also a ledge of red shale on the first north and south cross road to the west of West Hurley. The red shale at the base of the Catskill formation evidently crosses the rail-

[a] 13th annual report N. Y. state geologist, p. 300.

road and swamp not far west of West Hurley and forms the ridge on the southern side of Olive branch. The base of the formation crosses Esopus creek at Olive city where there are thick layers of red and green shales along the creek bank just above the bridge, and red shale on the road in the village. It then runs to the southeast and south on the hills to the south of the creek till on the hill east of Krumville church it turns westerly toward Samsonville. North of the stone church four and one half miles west of West Hurley are coarse, greenish gray sandstones on which are plain glacial striae running N 37° E. The dip of these sandstones is very great, being from 20° to 25° N, 70° E. To the southeast of the stone church near the township line between Hurley and Marbletown are extensive flagstone quarries in the Sherburne formation. Farther to the southeast near the head of the creek at the "Lapla nigger settlement" are bluish arenaceous shales and concretionary sandstones. By the highway down the creek are coarse, bluish arenaceous shales which contain Hamilton fossils. *Paracyclas lirata* (Con.) Hall is the most common and the other species are:

1	*Liorhynchus multicosta* Hall	(c)
2	*Chonetes coronata* (Con.) Hall	(rr)
3	*Nucula corbuliformis* Hall	(rr)
4	*Camarotoechia congregata* (Con.) H. & C.	(rr)
5	*Pleurotomaria* sp.	(rr)

These rocks along the creek into the valley of Esopus creek are in the Hamilton formation. On the south bank of the Esopus creek at the Hudson river pulp mill two and one half miles below Olive city are massive, greenish sandstones which form a rocky gorge and are apparently in the Sherburne formation. Loose in some bluish argillaceous shales are specimens of *Estheria* sp. apparently identical with those found near Oakhill. To the northwest of this hill no reds were seen on the road from Esopus creek to Olive branch.

The upper line of the Hamilton formation crosses the Ulster and Delaware railroad a short distance west of Bristol church, then is followed with difficulty across the rugged central part of

Hurley township, crossing Esopus creek below the Hudson river pulp mill, and then runs across the western part of Marbletown into Rochester. On the hill south of the Esopus creek about two and one half miles west of Marbletown are bluish, concretionary sandstones which are not far below the blue sandstone quarries at the three corners where one road turns to the south. The upper part of the sandstone ledge is heavy and crossbedded, below which are quite extensive flagstone quarries in bluish gray sandstone which alternates with bluish and greenish argillaceous shales. The dip is from $3\frac{1}{2}°$ to 4°N, 50°E and the quarries are in the Sherburne formation. Not far below the quarries are coarse, arenaceous, blue Hamilton shales in which are some fossils, as *Chonetes coronata* (Con.) Hall and fragments of a few other species. These shales are near the top of the Hamilton and some 225 feet below the base of the lowest reds on the hill above. This section gives the approximate thickness of the Sherburne formation at this locality.

At the northern end of the Lynesville pond about one and a half miles nw of Kripplebush is a small quarry in bluish Hamilton sandstone alternating with bluish shale, in which are Hamilton fossils, *Camarotoechia congregata* (Con.) H. & C. and *Tentaculites spiculus* Hall. Some of the rock contains quartz pebbles. To the west of Lynesville is the steep Mackey hill which is some two miles northwest of Kripplebush. On top of the hill are the Mackey flagging stone quarries, some of the stone being bluish gray in color and some banded grayish. The sandstone is in rather coarse layers and does not split into thin flags. It is capped by a considerable thickness of bluish argillaceous shale in which no fossils were found. There is a stratum of conglomerate six inches thick in which are red, black and various colored pebbles. The dip is between 4° and 5° N, 30° E. In the somewhat shaly partings are fossils, as *Spirifer mucronatus* (Con.) Bill., *Chonetes coronata* (Con.) Hall; *Camarotoechia congregata* (Con.) H. & C.; *Tropidoleptus carinatus* Hall; *Chonetes setigera* Hall; *Prothyris lanceolata* Hall and Crinoid stem, and the rocks are apparently in the Hamilton formation though near its top.

To the south of Mackey hill along the highway near Whitfield are fine blue Hamilton shales belonging in the lower part of the formation.

To the east of Tobasco and two and a half miles south of Samsonville are the Gray quarries. The dip is $5\frac{1}{2}°$ N, 80° W. The rock which alternates with greenish shales is a coarse, bluish gray, quite massive sandstone, which does not split into thin shales, and which shows crossbedding on the edge of the ledge. No fossils were found and the quarries are in the Sherburne formation.

The base of the red rocks on the hill south of Esopus creek runs southeasterly for several miles to the hill east of Krum corners, when it turns westerly toward Samsonville. This carries the Catskill formation somewhat farther east than is indicated on the *Geologic map of New York* and the valley to the west of Krum hill is in this formation instead of a lower one, for on the highway just north of Krum corners or Krumville church are red and green mottled, argillaceous shales. On the low hill just east of the road and 55 feet higher is a small quarry of coarse grained, bluish gray sandstone which splits into flags. There are partings of bluish, argillaceous shales in which are fragments of plants. The edges of the outcrop show crossbedding. The dip is 6° N, 70° W, and on another face of the quarry 2° N, 30° E. Near the corners where the first road north of Krum corners turns to the east are red shales which are to the southwest of the high hill shown as Catskill on the New York map. To the west of Krum corners is the Krumville postoffice and one quarter of a mile to the west on the bank of a brook is a quarry of bluish sandstone, some of the layers showing a reddish tint. There are plant fragments but no other fossils were found. The dip is 4° N, 70° W, and the quarry is near the top of the Sherburne formation for red sandstone apparently in place occurs on the highway to the west of the brook near the line indicated as the base of the Catskill formation on the state map. In Samsonville are conspicuous ledges of coarse grained, greenish to greenish gray sandstone which have a decidedly crossbedded

structure. These sandstones are specially conspicuous along the Rochester creek near the site of the abandoned tannery and they are near the base of the Catskill formation. Along the highway on the northern side of the creek one mile below Samsonville are outcrops of red and green shales, and above them is a heavy ledge of bluish sandstone in which a small quarry has been opened.

The base of the Catskill formation runs southwesterly from Samsonville, but it is difficult to follow the line closely on account of the heavy drift and infrequent outcrops. Along Mill brook above Mombaccus the country is well covered with drift and beds of sand and gravel. An occasional ledge of grayish sandstone is shown and near the head of the stream are loose pieces of red shale which apparently have not been transported far and probably came from near the base of the reds. Below Mombaccus the country is also well covered with drift and soil so that outcrops of bed-rock are infrequent.

On the eastern side of the Vernovy creek a little north of Wawarsing are fine Hamilton shales containing some fossils. The dip is very heavy being 35° slightly west of north. The shales near the base of the first small hill are quite fine and fossils are common though not abundant. The species however are few, *Liorhynchus* and *Chonetes* being the most common. The list is:

1	*Spirifer mucronatus* (Con.) Bill.	(rr)
2	*Chonetes coronata* (Con.) Hall	(a)
3	*Liorhynchus multicosta* Hall	(c)
4	*Camarotoechia congregata* (Con.) H. & C.	(r)
5	*Palaeoneilo constricta* (Con.) Hall	(rr)
6	*Paracyclas lirata* (Con.) Hall	(rr)
7	*Nuculites triqueter* Con.	(rr)
8	*N. oblongatus* (Con.) Hall	(rr)
9	*Nucula corbuliformis* Hall	(rr)
10	*Orthoceras constrictum* Van.	(rr)

Near the top of this hill the rocks become coarser and irregular; thin bedded sandstones occur showing a tendency to the

concretionary structure that is frequently seen in these coarser Hamilton deposits. The fossils are rare in these coarser layers. About half a mile above Wawarsing just above saw mill are coarse sandstones exposed by the side of the highway which have a dip of 38° N, 40° W. They are bluish in color and split into rather thin layers. A little farther up the road is a conspicuous ledge of bluish sandstone which splits into flagstones and a quarry has recently been opened in this ledge by the side of the highway. Ledges of red shale and sandstone cross the highway opposite the house of Mr Hillsdale, two miles above Wawarsing, about at the locality where the base of the Catskill is represented on the *Geologic map of New York*. Several years ago a well was drilled in Wawarsing to the depth of 1776 feet, the lower part of which is reported to have been in limestones.

The lower falls of Rondout creek in Napanoch are composed of the fine blue shales of the Hamilton formation which also appear along the highway toward Ellenville. These shales contain some fossils though neither species nor specimens are abundant. On the eastern side of Rondout creek just below Honk falls, which are not far above Napanoch, are blue sandstones which split into rather even flaggy layers. The dip is from 40° to 42° N, 20° W, while on the western side of the creek it is not much more than 30°. The cliff on the western side is perhaps 100 feet high, in which are some massive sandstone strata four feet or more in thickness, alternating with thinner layers. No fossils were found at the falls though the rocks are quite blue and in lithologic characters closely resemble the sandstones of the Hamilton formation. Not more than two miles above Napanoch on the eastern side of the creek the dip has decreased to about 12°. The first red shale seen in place occurs on this side of the creek between the two bridges some distance above Honk falls. Along the valley road from Kerhonkson to Ellenville there is a considerable amount of sand which also extends up the branches for some distance, as in the Rondout valley for two miles above Napanoch the roads on both sides of the creek are very sandy.

NAPANOCH FALLS, OVER THE HAMILTON

Red shales and sandstones outcrop conspicuously in the Beerkill and on the highway a short distance above the fork of the creek to the northwest of Ellenville. Along the creek below and under the bridge over the western fork the red rocks are very prominent and this locality is near the line representing the base of the Catskill formation on the *Geologic map of New York*. The older Devonian formations are not shown to any extent in the vicinity of Ellenville. The dip is 20°N, 50°W. At various places along the highway from Ellenville to Homowack are exposures of Hamilton shales and sandstones, the latter occuring more frequently. Against the eastern foot of the hill just north of Homowack is a big sand and gravel bank below which is an outcrop of Hamilton shales. These shales are bluish, not very arenaceous and break into blocky pieces. Only a few fragments of fossils were found. A little farther up the highway on the south side of Sandberg creek are bluish Hamilton shales which split into thinner layers than those first noted. The dip varies from 42° to 45°N, 50°W. Fossils, specially Lamellibranchs are more common than in the lower shales, being abundant in some of the coarser layers. This is the best locality for collecting noted between Kerhonkson and Homowack, the following species having been obtained:

1	*Nyassa arguta* Hall	(a)
2	*Palaeoneilo emarginata* (Con.) Hall	(c)
3	*P. constricta* (Con.) Hall	(r)
4	*Grammysia constricta* Hall	(rr)
5	*G. alveata* (Con.) Hall	(c)
6	*Cimitaria elongata* (Con.) Hall	(rr)
7	*Glyptodesma erectum* (Con.) Hall	(rr)
8	*Pterinea flabella* (Con.) Hall	(c)
9	*Nucula corbuliformis* Hall	(rr)
10	*Nuculites triqueter* Con.	(c)
11	*Goniophora hamiltonensis* Hall	(r)
12	*Liopteria dekayi* Hall	(r)
13	*Camarotoechia congregata* (Con.) H. & C.	(c)
14	*Tentaculites bellulus* Hall	(rr)
15	*Bellerophon* sp.	(rr)

16 *Discina doria* Hall (rr)
17 *Athyris spiriferoides* (Eaton) Hall (rr)
18 *Modiomorpha subalata* (Con.) Hall (?) (rr)
19 *Pleurotomaria* sp. (rr)

Above the bridge over Sandberg creek are decidedly olive argillaceous shales and some thick bedded, rather greenish sandstones apparently in the Sherburne formation. An outcrop of greenish blue flagstone by the highway two miles above Homowack has a dip of 6° N, 70° W.

SULLIVAN AND ORANGE COUNTIES

Sullivan co. in southern New York which forms the New York border for the greater part of the cañon of the Delaware river, is covered mostly by rocks belonging in the Catskill formation. The central part of Mamakating township however, the eastern township of the county, is crossed by the formations of the middle Devonian. In Orange co. the same formations cross Deer Park, which is its most western township, and enter Pennsylvania at Port Jervis. The strike of these formations is about parallel with the course of the Basherskill and Neversink river across these two counties, and in Pennsylvania with that of the Delaware for about 20 miles. In general the Marcellus shale is covered by soil in the valley of the Neversink river, and is succeeded to the westward by the Hamilton formation.

Distribution of the Middle and Upper Devonian

Along the valley road from Homowack through Phillipsport to Summitville the rocks are mainly covered with drift. By the side of the road a short distance north of Summitville are blocky Hamilton shales which contain a few fossils.

Exposed not far above the Wurtsboro hotel by the side of the highway are coarse, massive sandstones which are either in the upper part of the Hamilton or near the base of the Sherburne formation. Crossing the highway less than one mile northwest of Wurtsboro are red shales and sandstones which mark the base of the Catskill formation. The dip is between 14° and 15° N, 70°

W. Above the red rocks are massive greenish gray or grayish sandstones and green argillaceous shales. Succeeding these rocks is a prominent band of red argillaceous shale containing some green shale with a total thickness of between 40 and 50 feet. On the hill one and one half miles above Wurtsboro the rocks are nearly all covered by drift for some distance along the road.

By the side of the valley road over one half a mile southwest of Wurtsboro are fine, blue Hamilton shales, which contain some fossils, though they are not abundant. Perhaps one and one half miles below Wurtsboro is a good outcrop of these bluish, fine Hamilton shales, which contain but few fossils. The dip at this locality is 75° N, 50° W. In general this is the case with these somewhat blocky shales of the lower Hamilton as exposed along the valley road to the west of the Basherskill.

The rocks along the Pinekill in the southern part of Mamakating township for at least two miles above West Brookville are all covered by drift. The country is rough and there are large numbers of glacial boulders of various sizes.

On the hill just northwest of Cuddebackville are black argillaceous shales in the upper part of the Hamilton formation, containing abundant fossils. The following fauna was obtained from this outcrop:

1	*Paracyclas lirata* (Con.) Hall	(a)
2	*Nuculites oblongatus* Con.	(rr)
3	*Nucula bellistriata* (Con.) Hall	(rr)
4	*Tellinopsis subemarginata* (Con.) Hall	(c)
5	*Modiella pygmea* (Con.) Hall	(r)
6	*Leda rostellata* (Con.) Hall	(rr)
7	*Nucula corbuliformis* Hall	(r)
8	*Nuculites triqueter* Con.	(rr)
9	*Modiomorpha mytiloides* (Con.) Hall	(c)
10	*M. subalata* (Con.) Hall (?)	(rr)
11	*Macrodon hamiltoniae* Hall	(rr)
12	*Lunulicardium fragile* Hall	(rr)
13	*Spirifer fimbriatus* (Con.) Hall	(r)

14	*Ambocoelia umbonata* (Con.) Hall	(a)
15	*Chonetes setigera* Hall	(r)
16	*C. mucronata* Hall (?)	(rr)
17	*C. scitula* Hall (?)	(rr)
18	*Spirifer mucronatus* (Con.) Bill.	(r)
19	*Nucula randalli* Hall (?)	(rr)
20	*Dalmanites* (*Cryphaeus*) *boothi* (Green) Hall	(rr)
21	*Phacops rana* (Green) Hall	(rr)
22	*Pleurotomaria sulcomarginata* Con. (?)	(r)
23	*Bellerophon crenistria* Hall (?)	(rr)
24	*Orthoceras crotalum* Hall	(rr)
25	*Grammysia* sp.	(rr)
26	*Bellerophon* sp.	(rr)
27	(?) *Liopteria* sp.	(rr)
28	(?) *Pterinopecten* sp.	(rr)
29	Crinoid stems	

The base of the Catskill formation crosses the Neversink river just below Oakland. On the river bank at the lower Oakland bridge from 15 to 20 feet of red shale is exposed. At this locality a well was drilled between 1300 and 1400 feet in depth, and according to Mr Case after passing through from 18 to 20 feet of red shale at the mouth no more was struck, the remainder of the well being in "blue stone." This shows conclusively that the red shales on the river bank are the lowest reds in this valley. Years ago a well was drilled 500 feet deep in the Bushkill valley, where it joins the Neversink at Oakland, the first 50 feet of which was in a clear blue clay. This clay is frequently shown along the Bushkill valley. At the upper Oakland bridge on the eastern side of the Neversink river is a cliff of greenish gray sandstone and green and blue shale perhaps 75 feet high. No red shale occurs in it though the rocks are above the red shales at the lower bridge and in the Catskill formation.

In the small quarry at this place the dip varies from $\frac{1}{2}°$ to 1° N, 20° E, while in the quarry a little farther down the road the rocks are nearly horizontal, though the upper part of the ledge is so badly shattered that this horizontality may not continue

for any considerable distance. In general the rocks are well covered by drift along this part of the Neversink valley except on the steep bluffs, and boulders in large quantities have been swept into it.

At Rose Point on the Monticello and Port Jervis railroad is a cut showing an excellent exposure of Hamilton arenaceous shales and sandstones. The dip varies from 40° to 45° N, 30° W. These shales contain abundant fossils and it is one of the best localities in the Neversink valley for collecting. The fauna is as follows:

1	*Spirifer granulosus* (Con.) H. & C.	(c)
2	*S. medialis* Hall (?)	(rr)
3	*S. mucronatus* (Con.) Bill.	(rr)
4	*Tropidoleptus carinatus* (Con.) Hall	(rr)
5	*Nyassa arguta* Hall	(c)
6	*Nucula varicosa* Hall	(rr)
7	*Modiomorpha concentrica* (Con.) Hall	(rr)
8	*Chonetes mucronata* Hall	(r)
9	*Camarotoechia congregata* (Con.) H. & C.	(r)
10	*Athyris spiriferoides* (Eaton) Hall	(r)
11	*Chonetes deflecta* Hall (?)	(rr)
12	*Ambocoelia umbonata* (Con.) Hall	(c)
13	*Palaeoneilo emarginata* (Con.) Hall	(r)
14	*Nucula corbuliformis* Hall	(r)
15	*Nuculites triqueter* Con.	(rr)
16	*Palaeoneilo constricta* (Con.) Hall	(rr)
17	*P. plana* Hall (?)	(rr)
18	*Nyassa recta* Hall (?)	(rr)
19	*Modiomorpha subalata* (Con.) Hall (?)	(c)
20	*Macrodon hamiltoniae* Hall	(rr)
21	*Grammysia bisulcata* (Con.) Hall	(rr)
22	*Homalonotus dekayi* (Green) Emm.	(r)
23	*Dalmanites (Cryphaeus) boothi* (Green) Hall (?)	(rr)
24	*Pleurotomaria sulcomarginata* Con. or *P. itys* Hall	(c)
25	*Bellerophon patulus* Hall (?) possibly *B. natator* Hall	(rr)
26	*Loxonema delphicola* Hall	(rr)

27 *Orthoceras crotalum* Hall (rr)
28 *Conularia undulata* Con. (rr)
29 *Lepidodendron gaspianum* Du. (rr)
30 (?) *Psilophyton princeps* Du. (rr)
31 *Pterinea flabellata* (Con.) Hall (rr)
32 *Actinopteria boydi* (Con.) Hall (r)
33 *A. decussata* Hall (?) (rr)
34 *Streptorhynchus chemungensis* (Con.) Hall (rr)
35 *Platyceras* sp. (rr)
36 Two specimens of *Pectinidae*

On the lower part of Prospect hill above Rose Point are rather thin bedded bluish gray sandstones. In some of the slightly shaly partings are fossils, a number of specimens closely resembling *Spirifer mesastrialis* Hall, but the surface is so poorly preserved that the striae are shown only very faintly. The following species were obtained:

1 *Spirifer mesastrialis* Hall (a)
2 *Camarotoechia* sp. (rr)
3 *Lepidodendron* (rr)

Along the highway somewhat higher are ledges of thin flaggy stone which split into layers from one half to one inch thick. The rock is of a slightly greenish tint, and very arenaceous and fossils are common. The species mentioned in the following list were collected at this locality:

1 *Spirifer mucronatus* (Con.) Bill. (?) (aa)
2 *Tropidoleptus carinatus* (Con.) Hall (a)
3 *Palaeoneilo constricta* (Con.) Hall (rr)
4 *Cyrtina hamiltonensis* Hall (rr)
5 *Microdon (Cypricardella) gregarius* Hall (c)
6 *Paracyclas lirata* (Con.) Hall (rr)
7 *Modiomorpha subalata* (Con.) Hall (?) (rr)
8 *Actinopteria boydi* (Con.) Hall (?) (rr)
9 *Chonetes mucronata* Hall (?) (rr)
10 *C. setigera* Hall (rr)

Plate 24

Hills to the south of Port Jervis

The exposures on Prospect hill to the west of the Neversink river show that the modified Ithaca fauna as found in Schoharie county is reappearing above the regular Hamilton fauna. From Albany to Orange county between the regular Hamilton fauna and the lowest reds there is hardly any trace of the Ithaca fauna. The explanation being, apparently, that the reds appeared as early in time as the Ithaca and so drove out the fauna of that time. But from Orange co. to the southwest across northeastern Pennsylvania the base of the reds was apparently later in time, and the modified Ithaca fauna flourished in this region. This is well shown by the various lists of fossils published several years ago by the writer, though at that time he termed the formation the lower Portage,[a] and his discussion of the correlation adopted by the second geological survey of Pennsylvania.

Along the road across the top of Prospect hill there are plenty of outcrops of thin bedded, bluish gray, micaceous sandstones which are in the Sherburne or Ithaca formation. No fossils were found on a hasty examination, and no reds were seen in place, showing that the base of the Catskill is farther to the west. Along the lower part of the hill road to the northwest of Huguenot are blue fossiliferous shales of the Hamilton formation.

The western side of the Neversink valley for some miles above Port Jervis as well as the Pennsylvania side of the Delaware valley below Port Jervis is bounded by a line of high and precipitous hills. The greater part of the ridge is composed of Hamilton rocks with an occasional outcrop of Marcellus shale at its base. The dip is strongly westerly as is clearly shown by the lines of the more massive sandstones where the Delaware river has cut through the ridge to the northwest of Port Jervis and Matamoras. In northeastern Pennsylvania a number of streams have cut gorges in this ridge, forming falls and showing the rocks in an admirable manner for geological study. One of these glens in the Sawkill at Milford is shown in one of our plates.

[a] Am. jour. science 3d ser. 46:212, and Bull. U. S. geol. surv. no. 120.

and an account of its geology which is most interesting has been described in an earlier work by the writer.[a] To the northwest of Port Jervis are frequent outcrops of Hamilton shales and sandstones which contain an abundant fauna, and some of these were described in the work mentioned above.[b]

On the Pennsylvania side of the Delaware river below the Erie railroad bridge four miles above Port Jervis are thin blue sandstones alternating with bluish, rather arenaceous shales. Some of the sandstone layers have a warped or undulating structure and there are concretionary layers. Fossils are rare and this sandstone lithologically resembles the Sherburne flags of Ulster co. to which formation these rocks are referred. Above the Erie railroad bridge both on the river bank and in the cut near the 91st mile post are bluish sandstones and shales which contain a fauna similar to that of the Ithaca formation in Schoharie and Otsego counties, to which these rocks are referred. On the bank of the river at Mill rift in bluish thin bedded sandstones to shales the following species were collected. A thin layer of the bluish shales contains more abundant fossils than the other rocks, specially *Paracyclas lirata* (Con.) Hall and other Lamellibranch shells. A sort of concretionary stratum not much above the water level at low tide contains fragments of fish bones associated with *Spirifers*. The list is:

1	*Spirifer mucronatus* (Con.) Bill.	(a)
2	*Tropidoleptus carinatus* (Con.) Hall	(rr)
3	*Chonetes setigera* Hall	(rr)
4	*C. lepida* Hall	(rr)
5	*Camarotoechia eximia* (Hall) H. & C. (?)	(rr)
6	*Liorhynchus mesacostalis* Hall	(rr)
7	*Paracyclas lirata* (Con.) Hall	(c)
8	*Microdon (Cypricardella) gregarius* Hall	(c)
9	*Goniophora carinata* (Con.) Hall	(rr)
10	*Glossites depressus* Hall (?)	(rr)
11	*Actinopteria boydi* (Con.) Hall	(rr)

a Bull. U. S. geol. surv. no. 120, p. 34-39.
b Ibid p. 39-42.

Plate 25

Hamilton cliff west of Port Jervis on New York side of Delaware river.

12 *Homalonotus dekayi* (Green) Emm. (rr)
13 Fish bones (fragments) (c)

From the Erie railroad cut near the 91st mile post the following species were obtained:

1 *Spirifer mesastrialis* Hall (rr)
2 *Palaeoneilo emarginata* (Con.) Hall (rr)
3 *P. plana* Hall (rr)
4 *Leda diversa* Hall (r)
5 *Microdon (Cypricardella) tenuistriatus* Hall (?) (rr)
Possibly *M. gregarius* Hall but it resembles the former more closely.
6 *Orthonota carinata* Con. (rr)
7 *Paracyclas lirata* (Con.) Hall (rr)
8 *Grammysia subarcuata* (?) (rr)
9 *Modiomorpha mytiloides* (Con.) Hall (?) (rr)
10 *M. subalata* (Con.) Hall
var. *chemungensis* Hall (?) (rr)
11 *Liorhynchus* sp. (rr)
12 *Actinopteria boydi* (Con.) Hall (a)
13 (?) *Psilophyton princeps* Dn. (r)
14 (?) *Crania* sp. or possibly *Discina* sp. (rr)

On the New York side of the river the rocks form a steep cliff 200 feet or more in hight at a place known as the Hawk's nest. The dip as determined from the canal below is between 6° and 7° N, 10° E. No red rocks were seen in this cliff either from the canal or the Hawk's nest road. On the hill toward Mongaup is a thick deposit of sand and the older rocks are well covered by it and drift. There is apparently another sand hill on the western side of the river nearly opposite the Hawk's nest. On the Pennsylvania side just below the Pond Eddy station is an exposure of 17 feet of red shale. This is probably not the base of the red rocks but it is certain that the base is several miles above the Erie railroad bridge where the base of the Catskill formation is represented as crossing the river on the *Geologic map of New York* and it has been so indicated on the accompanying map.

CONCLUSION

In the conclusion of part 1 of this report some general results were stated, but it is now thought best to summarize very briefly all the important results of this investigation.

1 It was shown that from Cortland county east across Chenango, Otsego and Schoharie counties the line marking the upper boundary of the Hamilton formation is from 5 to 15 miles farther north[a] than it was drawn on the *Preliminary geologic map of New York.*

2 The Tully limestone extends eastward to Smyrna in the Chenango valley and of course for that distance clearly indicates the top of the Hamilton formation. Above the limestone at Smyrna is the Genesee slate nearly 30 feet thick which was not clearly recognized to the east of the Chenango river.

3 The horizon of the Tully limestone is indicated in New Lisbon township in the southern part of Otsego county by the occurrence of its characteristic fossil *Rhynchonella (Hypothyris) venustula* Hall. This discovery extends the distribution of the species 30 miles farther southeast than heretofore reported.

4 Succeeding the Tully limestone and Genesee slate, or farther east where these formations have disappeared, the Hamilton formation, is a mass of thin bluish sandstones and smooth shales of Portage age, for which Vanuxem proposed the name "Sherburne flagstone" which has been adopted and used as the name for the formation. It has a thickness of 250 feet in the Chenango valley and may be readily traced westward to the meridian of Cayuga lake, west of which Prof. J. M. Clarke has shown that it gradually passes into the Naples beds. Eastward from the Chenango valley the Sherburne formation crosses Chenango, Otsego and Schoharie counties, entering Albany co. where it turns south-southwesterly, and apparently extends to the Delaware river crossing Greene, Ulster, Sullivan and Orange counties. Where the Sherburne formation is separated from the Hamilton by the

[a] By a typographical error on p. 220 of part 1 of this report the writer was made to say *south* instead of *north*, but from the numerous statements in the descriptive portion of the paper concerning this boundary the mistake would be apparent to one specially interested.

HAMILTON. SAWKILL FALLS, MILFORD, PA.

Tully limestone and Genesee slate, fossils are comparatively rare in it, but to the east of the Chenango valley in Otsego and Schoharie counties they are more common and constitute a modified Hamilton fauna. In eastern New York across Greene and Ulster counties the upper part of the flagstones or "North river blue stone" is apparently in the Sherburne formation, but contains scarcely any fossils except occasionally a few species of plants.

5 Above the Sherburne is the Ithaca formation which has a thickness of 500 feet in the Chenango valley and extends from the vicinity of Keuka lake where it has been shown by Prof. Clarke that the "Portage or Naples fauna prevails largely to the exclusion of representatives of the Ithaca fauna"[a] eastward across Schuyler, Tompkins, Cortland, Chenango, Otsego and Schoharie counties. In eastern New York across Albany, Greene, Ulster and Sullivan counties the physical conditions which existed during the deposition of the Oneonta and Catskill formations appear to have also prevailed during Ithaca time and perhaps they began in the Sherburne, so that there is very little evidence of the Ithaca fauna, the fossiliferous, bluish and grayish shales of the more western counties being replaced by the unfossiliferous red and greenish shales and sandstones. In Orange county and northeastern Pennsylvania there is some representation of the Ithaca fauna, the reds appearing later as one follows this series to the southwest. Prof. Clarke has clearly shown that the Ithaca fauna in the Chenango valley is composed of "a more abundant representation of unmodified Hamilton species" than in the Ithaca region,[b] which is also true to the east of the Chenango valley as demonstrated by the numerous lists of fossils given in this report.

6 From the Chenango valley eastward the Ithaca is capped by the Oneonta formation which is composed of red and green shales, reddish sandstones and coarse grained grayish to greenish gray sandstones. These rocks are nearly unfossiliferous, containing only an occasional specimen of *Archaeopteris* and *Amni-*

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a 15th an. rep't N. Y. state geol. p. 81 and "Geological map showing the distribution of the Portage group."

b Ibid. p. 46-63.

genia catskillensis (Van.) Hall. The formation has a thickness of 550 feet in the Chenango valley and as the physical conditions under which the Oneonta was deposited appeared earlier to the eastward it gradually thickens in that direction till in Albany and Greene counties it completely replaces the Ithaca formation.

7 The Chemung formation east of the Susquehanna river rapidly thins to the eastward on account of the earlier appearance of the physical conditions which prevailed during the deposition of the Catskill formation, so that the lithologic characters of the Chemung are gradually replaced by those of the Catskill, and as this change takes place the Chemung fauna disappears till the farthest east it was noted was near Spring lake northwest of Delhi where a small Chemung faunule occurs above red shales. Search in the rocks occurring at the horizon of the Chemung formation east of the Delaware river was not rewarded with any fossils and the lithologic appearance of these rocks is similar to that of those composing the Oneonta and Catskill formations.

8 In eastern New York in Albany, Greene, Ulster and Sullivan counties the physical conditions under which the Oneonta and Catskill formations were deposited began as early as Sherburne time and continued throughout the remainder of the Devonian period. The representation of the Ithaca or Chemung faunas is very slight and this great mass of rocks consists mainly of alternations of red and green shales and sandstones and gray to greenish gray, coarse grained sandstones with some conglomerates in the Catskill mountains. In the Delaware valley the red rocks do not appear as early and there is some representation of the Ithaca fauna which is more pronounced in northeastern Pennsylvania. As this series of rocks is followed along the Appalachians southwesterly across Pennsylvania, Maryland and the Virginias it is found that the reds gradually appear later and the Chemung fauna is present. For in western Maryland, succeeding the black shales with a Genesee fauna at the top of the Hamilton, are first nearly barren smooth shales and sandstones like the Portage of western New York, then rougher shales and rather mealy sandstones containing an abundant Chemung fauna with

numerous specimens of *Spirifer disjunctus* in Garrett county and finally the red and grayish shales and sandstones of the Catskill. This change from the Catskill mountain region to the southwest is found to be quite similar in general characters to the change from these mountains westward across southern New York, the story of which was excellently told some years ago by Prof. Stevenson in his address before the American association for the advancement of science.[a]

Correction. On the "Geologic map of parts of Chenango, Madison, Otsego, Schoharie, and Albany counties" accompanying part 1 of this report, published in the 15th annual report, the southern margin of the colored area is not intended to represent the boundary either of the Chemung or Oneonta formation. The engraver has made the line a regular one as though it represented a boundary, while it was intended to have been an irregular, broken one which would have shown clearly that it is not to be considered the southern boundary of those formations.

a The Chemung and Catskill (upper Devonian) on the eastern side of the Appalachian basin. Proc. American ass'n adv. science, 1892, 40:219-48.

Appendix

Upper Devonian fish-fauna of Delaware county, New York

By C. R. Eastman

The following notes are based on a small collection of fossil fishes from the base of the Catskill formation in Delaware county, New York, together with a few specimens from the Chemung group near Franklin Station in the same county and one or two other localities, which were collected by Prof. Charles S. Prosser during the prosecution of his geologic survey of this region, and were turned over by him to the writer for examination and report.

The material may be said to be fairly representative, and though its state of preservation is not so favorable as one might desire, yet it is fully as good as the average that can be obtained from rocks of this age in New York state. Most of the specimens show signs of having been drifted about by currents prior to deposition. The plates of *Bothriolepis*, for instance, are invariably found detached, and their ornament more or less abraded. But though the heavier fragments have suffered severely, delicate objects like the scales of crossopterygians sometimes occur almost wholly uninjured. The latter probably became detached and covered with sediment very close to the spot where the dead creature finally sank to the bottom.

Although our knowledge of the higher Devonian fish-fauna in the eastern states is based for the most part on incomplete specimens, there is reason to expect it will become greatly augmented in the course of time, since the variety of fragments already discovered indicates a considerable diversity even as early as the Lower Devonian. It is impossible not to derive some information from the comparison of large numbers of dissociated parts; and among the latter there is always the chance of some

exceptionally perfect specimen turning up at any moment, which may afford the key to unsolved problems. The commonly despised "fish-fragments" are therefore entitled to greater respect than most collectors have allowed, and by all means should find their way into repositories where they may be preserved and freely consulted.

The chief interest of the present collection centers in its assortment of *Bothriolepis* remains, the appendages and various plates of the dermal armor being illustrated by more than a score of specimens. The species *B. minor* was originally described from Chemung rocks, and has not been heretofore reported from the Catskill formation. The occurrence of a Catskill dinichthyid and a spine of *Onchus*, as well as scales of *Holoptychius americanus* in the Ithaca group are likewise matters of general interest. The principal "fish-bed" of the Upper Devonian in New York and Pennsylvania has been referred by most writers to the base of the Catskill, though some have placed the line of demarcation higher up, owing to the persistence of typical Chemung fossils. At all events it lies near the upper limit of the Chemung formation, and in view of the general migration of forms during these epochs, it is not surprising that some intermingling of species, specially of free-swimming chordates, should be observed. The New York localities, however, yield a considerably smaller number of species than those in the northern tier of counties in Pennsylvania.

FISH-FAUNA OF THE ITHACA AND CHEMUNG FORMATIONS

Family Coccosteidae

Genus DINICHTHYS

The only species of *Dinichthys* hitherto described from the Chemung is *D. tuberculatus* Newb., founded on detached fragments from Warren, Pennsylvania (type in Yale museum). This species is remarkable for the relatively great thickness of its dermal plates and their coarsely tuberculate style of ornamentation. Fragments that are indistinguishable from those found at the

typical locality occur in the Corniferous of Ohio, Hamilton of Milwaukee, and Upper Devonian of Johnson co., Iowa.

Newberry[a] describes but does not figure a small dorso-median plate referred to *D. tuberculatus* of which the anterior half only was preserved. He noticed "a strong keel on the under surface," but though warranted in assuming that the latter "terminated behind in a neck-like process projecting downward," it is apparent from his own statement that the latter was not observed. Had Newberry possessed other and more perfect examples of this plate, he could not have failed to notice their resemblance to his *D. precursor*, from the Corniferous of Ohio. A comparison of the type of the latter "species" with several other homologous plates from the Chemung of Warren, Pennsylvania, now preserved in the museums of Columbia and Yale universities, leads the writer to believe that *D. precursor* and *D. tuberculatus* are identical, in which case the latter name takes precedence.

Lest the objection be raised that the Chemung plates exhibit a somewhat different outline anteriorly from Newberry's figure of *D. precursor*, the fact must not be overlooked that the latter is not strictly accurate. Newberry[b] states that "the keel of the under side is buried in the rock, and its form can not be made out." The truth is that the keel, which lay uppermost and was exposed, has been almost entirely broken away; and the *dorsal* side of the plate is embedded in the rock, or where abraded or corroded away, has left its impression in the rock. A restoration to the left antelateral margin is indicated by the dotted outline in plate 41, but the figure leads one to suppose that the corresponding antelateral margin on the right-hand side of the specimen was entire, which is not the case. The impression in the rock is so faint and confused that it is difficult to trace the outline of the anterior fourth of the plate; but it is certain that the antelateral angle was acute instead of being rounded, and was gently curved inward instead of flaring outward as shown. The chief peculiarities of this shield, as noted by Newberry, are

a Newberry, J. S. The palaeozoic fishes of North America (Monogr. U. S. geol. surv. 1889, 16:98).
b Ibid. p. 51.

first its tuberculation; and second, the fact that the keel terminated before reaching the posterior margin; and in both these respects the plates of *D. tuberculatus* stand in perfect agreement.

Dinichthys sp.

The specimen shown in the accompanying figure has the outlines very distinctly preserved, but the substance of the bone has been considerably worn or broken away. It obviously represents the anterior portion of the mandible belonging to some Arthrodire, for the microscopic structure proves it is not of chimaeroid nature. Hence it is most naturally referred to *Dinichthys*, but we are unable to identify it with any known species. *D. minor* and *D. gouldi* are the nearest of the Ohio forms with which it can be compared, but at best very remotely. Unfortunately, mandibles have not yet been found associated with fragments of *D. tuberculatus* in either of the horizons where it occurs, and as this is the only contemporaneous species known, it is natural to think of it in connection with the present mandible. The size, also, is not incompatible with the plates of *D. tuberculatus;* but as conjectural associations are for the most part unwise, we prefer to leave the species as indeterminable. The sinuous posterior cutting edge of the beak and general chimaeroid outline are noteworthy features.

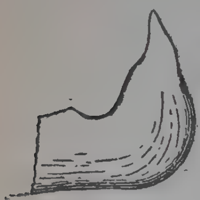

Fig. 1 *Dinichthys* sp. Anterior extremity of mandible.

Locality; railroad cut one quarter mile north of Franklin Station.

Family Holoptychiidae

Genus HOLOPTYCHIUS

The first observer who recognized that *Holoptychius* and *Bothriolepis* do not belong exclusively to the Catskill fauna, and who found their remains in New York state, seems to be E. W. Claypole.[a] The species was not determined by him, but may have

[a] Claypole, E. W. Note on the occurrence of Holoptychius in Bradford county, etc. (Proc. Amer. phil. soc., 1883, 20:581).

been identical with some of the forms described by Newberry in 1889 from the Chemung of Pennsylvania. A scale belonging to an undetermined species of *Holoptychius* is also mentioned by H. S. Williams[a] as occurring in the Chemung sandstone of Wellsville, Allegany co., New York. *H. americanus* has not been hitherto reported from a lower horizon than the Catskill, hence Prof. Prosser's discovery of a scale in the Ithaca beds extends the range of this species a considerable distance backward. Previous to this the only other fish-remains yielded by the Ithaca group are the doubtfully determinable jaw described by Prof. Williams[b] a few years ago as *Dipterus ithacensis*, and a supposed Dinichthyid fragment.

Holoptychius americanus Leidy

An impression of the outer surface of a scale obtained from the Ithaca formation at Jefferson shows the characteristic markings of this species. The scale is cycloidal, measures nearly 2 cm in diameter, and is traversed by moderate-sized inosculating ridges which are not broken up into tubercles. It was possible to take a very clear reverse impression in wax, which facilitated the determination.

Locality; south of Jefferson, Delaware co.

Family **Onychodontidae**

Genus ONYCHODUS

Onychodus sigmoides Newberry

This species, like *Dinichthys tuberculatus* ranges from the Corniferous to the Chemung, but teeth occurring in the latter horizon were regarded by Newberry as constituting a separate species (*O. hopkinsi*), distinguished by its somewhat smaller size. The average hight of the Chemung teeth is about 3 cm, but gradations occur all the way up to 6 cm, and it is doubtful if this size is exceeded by any of the Corniferous examples. None of the Chemung teeth were figured by Newberry, but he thus summarizes their salient characters: "Teeth generally about 1 inch in length,

[a] Williams, H. S. On the fossil faunas of the Upper Devonian (Bull. U. S. geol. survey, 1887, no. 4, p. 78).

[b] Proc. Amer. ass'n adv. sci. 1881, 30: 193.

conical, acute, and simply curved. Occasionally, however, the point is slightly curved forward, giving a hint of the sigmoidal curve which is so conspicuous a feature in the great species of the Corniferous limestone (*O. sigmoides*)."[a] Experience shows that the curvature is a variable quantity, and that the sigmoidal outline occurs among the Chemung as well as among the Corniferous specimens; hence the necessity for maintaining *O. hopkinsi* as a separate species disappears.

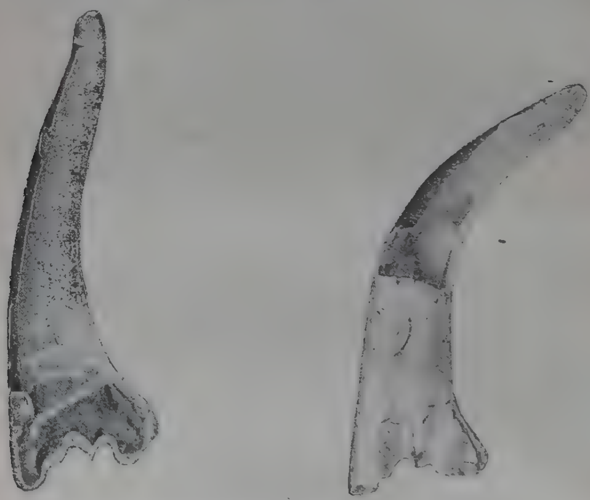

Fig. 2, 3. *Onychodus sigmoides*, Newb. Presymphysial teeth—Chemung group.

Prof. Prosser obtained two impressions of the crown from near Franklin, but as these were imperfect we have selected two other specimens from the same locality for purposes of illustration. The original of fig. 2 belongs to the Dyer collection, in the Museum of comparative zoology at Cambridge, and the other is preserved in the collections of the state museum at Albany.

Other specimens of fish-remains from the New York Chemung have been found by H. S. Williams near Rushford, Allegany co., and comprise teeth, *Ctenodus nelsoni* and *C. levis* (?), besides "numerous fragments of fish-bones and a fish-jaw."[a] As one of the teeth is doubtfully determinable as *Ctenodus levis*, the alternative title *C. alleghaniensis* is proposed for it by Prof.

[a] Loc. cit. (1889) p. 99.

Williams in case its identity with Newberry's species should be ultimately disproved. He also cites the discovery by Dr J. M. Clarke of "the anterior extremity of a mandible of *Rhynchodus;*"[b] identified by Dr Newberry.

A second Chemung specimen representing the lower dorsal plate of an undescribed species of Rhynchodus is preserved in the Cambridge museum.

The Chemung of northern and western Pennsylvania is much richer in fish-remains than New York state.

FISH-FAUNA OF THE CATSKILL FORMATION

Family Ichthyodorulites

Genus ONCHUS

Onchus rectus sp. nov.

A new species of selachian fin-spines is apparently represented by two specimens in the collection, the most perfect of which is shown in the annexed figure. This is 5 cm long, and .4 cm in maximum width; it is straight, as indicated by the name, and tapers gradually to an acute point. The inserted portion is round in section, and covered with almost microscopic longitudinal striae; the exserted portion on the other hand is laterally compressed, being less than .2 cm in thickness. The anterior margin is evenly rounded, and very delicately striated. The lateral face is traversed by a number of fine longitudinal ridges, as many as 10 being counted in the widest portion. These are nonbifurcating, and are all of uniform size and regularly spaced with the exception of the anterior one, which is twice the width of the others, and is round in section, while the rest are triangular.

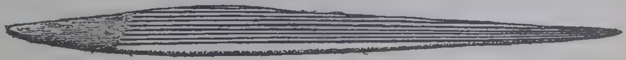

Fig. 4. *Onchus rectus*, sp. nov. Dorsal fin-spine.

Fine striae are observable with a lens along the sides of the costae. The latter have their origin along a slightly oblique line

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a Williams, H. S., loc. cit. (1887) p. 62, 63, pl. 3, fig. 1, 2.

b Idem. On a remarkable fauna at the base of the Chemung (Amer. journ. sci. [3] 1883. 25:98).

extending upwards and backwards, but there is no very sharp demarcation between the base and the exserted portion. Neither the spine itself nor its impression in counterpart show any traces of posterior denticles, a fact which serves to exclude it from the genus *Hoplonchus*, and justifies the present determination. The general form is comparable with that of *O. murchisoni*, but is more rectilinear; and in ornamentation there is a strong resemblance to *O. tenuistriatus*. Both of these species persist as late as the lower old red sandstone, but no Devonian species of *Onchus* has as yet been described from this country.

Locality; Ontario and Western railroad tunnel between Murickville and North Walton, Delaware co.

Family **Asterolepidae**

Genus BOTHRIOLEPIS

Bothriolepis leidyi Newberry (?)

Though this is a characteristic Catskill species, all the remains of *Bothriolepis* in the collection are assignable to *B. minor* with one exception, which may be somewhat doubtfully referred to *B. leidyi*. This specimen is so abraded as to render an accurate determination impossible, but the ornament is certainly suggestive of *B. leidyi*, though on the other hand the thickness of the plate is excessive for that form. The identification must therefore be regarded as provisional only.

Locality; same as preceding.

Bothriolepis minor Newberry

This species has heretofore been supposed to be confined to the Chemung group, but Prof. Prosser has succeeded in obtaining an extensive series of plates from the Catskill which show the characteristic ornamentation described by Newberry. The plate of most frequent occurrence is the antedorso-median, but it is seldom found entire. Under the designation of "scutes, upper and lower surfaces," Newberry figures the dorsal aspect of this element in plate 20, fig. 6-8 of his monograph, and in fig. 4 and 5 shows the same plate in *B. leidyi*, all more or less imperfect,

and with the exception of fig. 7, all turned with the posterior end uppermost.

The orientation of this plate is capable of positive determination, whether the rugose external crust is preserved, or only an impression of the visceral surface of the bone remains. In case the ornamentation is preserved well enough to show the divergent sensory canals, it need only be borne in mind that these meet at an angle near the center of the plate with the apex of the V directed anteriorly. When the bone-substance has been denuded so as to leave a smooth impression of the visceral surface, as shown in fig. 4, we notice first of all a median keel, which traverses the plate for about three quarters of its length. Frequently the keel itself is more or less worn away, its position being marked by a longitudinal groove, widest a little in advance of the middle of the plate, and terminating slightly before the posterior margin. The keel is met on either side anteriorly (at a distance behind the anterior margin equal to about one fourth the length of the plate) by a sharp ridge depending from the under surface, and extending forward and outward nearly to the anterior margin. These ridges diverge from the median keel at a somewhat lesser angle than that formed by the junction of the sensory canals, and it often happens that the area included between them is broken off from the rest of the plate. In some specimens the keel appears to terminate at the junction of these ridges, but in others it continues faintly almost as far as the anterior margin.

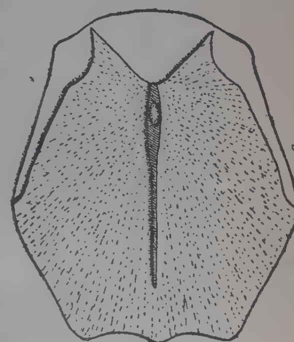

Fig. 5. *Bothriolepis minor* Newb. Antedorso-median plate denuded of outer crust.

Apparently some structural difference exists between the borders of the plate where it overlaps contiguous elements (antedorso-laterals), and the central portion. Possibly the bone is denser near the edges than elsewhere, but at all events it is usual to find the margins preserved as far as they are overlapped, even where the ornament has been worn smooth as shown in the

figure, while the central area has been entirely denuded. This gives rise to the appearance of a raised border along the antelateral edges, sometimes ornamented but in other cases smooth, as shown in plate 20 fig. 5 and 6 of Newberry's monograph. Similar raised borders have been observed in other plates besides the antedorso-median, thus indicating that all are the product of the same cause, and are correlated with the condition of overlap.

The collection also contains two pectoral appendages belonging to the left side of the body, one of them being preserved in counterpart. They are about the average size of those in *B. leidyi*. Some of the ventral plates likewise indicate less disparity in size of the two species than has commonly been supposed. No examples of the head portion are represented in the collection.

Locality; same as preceding.

Family **Coccosteidae**

Genus DINICHTHYS

Dinichthys sp.

The dinichthyid plate of which the visceral aspect is shown in the annexed figure is identifiable as the left anteventrolateral. It is nearly entire, lacking only a small piece from each of the antelateral angles. In length it measures 4.4 cm, and in maximum breadth 2.8 cm. It is quite thin, and this circumstance taken together with its outline and rugose markings on the posterior and inner margins, due probably to overlap, compel us to refer to it to the ventral surface of the body. There is an obvious similarity in outline to the corresponding plate in *D. minor*,[a] and a lesser resemblance to the same element in *Coccosteus*. As the external surface is firmly embedded in the matrix, it is impossible to observe the nature of the ornamentation, and hence a specific determination is quite

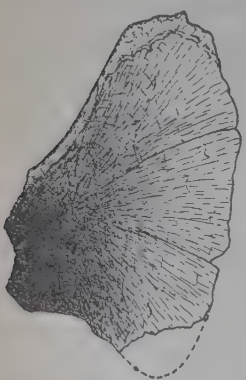

Fig. 6. *Dinichthys* sp. Visceral surface of right anteventrolateral plate.

a Cf. Newberry, J. S., loc. cit. (1889). pl. 47, fig. 2.

impossible. In point of size, however, it would correspond to a young individual of *D. tuberculatus* from the Chemung. No species of *Dinichthys* has yet been described from the Catskill, and it is therefore to be hoped that further material of this nature may be forthcoming.

Locality; Kaaterskill creek above Palenville.

Family Holoptychidae

Genus HOLOPTYCHIUS

Holoptychius americanus Leidy

Scales of this species are quite abundant in the Catskills, and were obtained in considerable numbers from the same locality as *Onchus* and *Bothriolepis*, *i. e.* from the Ontario and Western railroad tunnel between Murickville and North Walton, in Delaware co.

Associated with the above were several specimens illustrative of the scales and bone-fragments of some unknown fish, probably of crossopterygian nature. The scales are about 2 cm in diameter, and somewhat elliptic in outline. The external surface is smooth without being either polished or enameled, and under a lens is seen to be covered with innumerable minute conical granules. The latter are hollow, and consequently appear as pores on abraded or fractured specimens. The thickness of the scales varies between 1 and 1.5 mm, and the under surface of some bears a prominent articulating ridge. The generic and even family position of these objects must be regarded for the present as indeterminable.

Locality; same as preceding.

STRATIGRAPHIC GEOLOGY OF THE EASTERN HELDERBERGS

BY

CHARLES S. PROSSER AND RICHARD B. ROWE

CONTENTS

INTRODUCTION

The eastern escarpment of the Helderberg plateau, generally termed the Helderberg mountains, forms one of the most striking topographic features of central eastern New York. The most prominent portion of this escarpment is in the central part of Albany co. in New Scotland township where it turns from a southerly to a westerly direction. To the south of New Scotland the Helderberg and Catskill mountains form for many miles the western boundary of the Hudson river valley, while to the west of New Salem the escarpment forms the northern boundary of the great plateau region of southern New York which has recently been well termed by Prof. Tarr the New York-Pennsylvania plateau province.[a] An excellent view of the most rugged part of the Helderberg mountains is offered every traveler on the N. Y. C. & H. R. railroad on leaving Albany who on looking out of the car window toward the west will see a steep mountain ridge rising from 1000 to 1300 feet above the general level of the Hudson river valley. Not only is the region famous for its natural scenery but the massive limestones which form cliffs from 50 to 100 feet in hight are familiar by name at least to every geologist as the Helderberg limestones. Prof. James Hall has made numerous trips to this region and the Schoharie valley and has added some hundreds to the known species of fossils so that the locality has become a classic one. Indeed, the great English geologist Lyell is reported to have said after visiting the Helderberg region that no one could consider himself a perfectly trained geologist until he had seen the Helderberg mountains, and it is well known as a favorite locality of Louis Agassiz for geological study.

However when the writer came to study the geology of this extremely interesting region he found that no one had published a precise geological section of the northern Helderbergs. Since no less than 10 different geological formations are exposed in the

[a] Bull. Am. geog. soc. 1896. 28:106.

eastern Helderberg escarpment and since it would be difficult to find a locality in New York at which the stratigraphic position of a similar thickness of rocks is as clearly shown, and finally since it is the typical locality for the Lower Helderberg series it seems important that the thickness, lithologic and faunal characteristics of typical sections of the northern Helderbergs should be published. Mather in 1843 in using the name "Helderberg division" for the rocks forming the northern end of the Helderberg mountains, stated that "in consequence of these rocks being so well developed on the Helderberg mountains, and their forming a natural group, strongly marked in their lithological and paleontological characters from the strata lying above and below them, the term of Helderberg division is used to designate them."[a]

This division included all the formations found in the northern Helderbergs from the top of the Hudson to the base of the Marcellus shale. Mather's classification has not been generally adopted but the name Helderberg is perpetuated in geological classification by the Lower Helderberg period or series.

The general geology of the Helderberg region has been more or less fully described by various geologists. The first work describing to any extent the geology of Albany co. is that by Eaton and Beck in 1820.[b] At least a third of the work is devoted to a discussion of the different varieties of soil and their treatment and naturally enough the geological portion is very crude. "A section of the Helderberg" is given on p. 55 which was apparently made farther north than Countryman hill. At the base is a "compact limestone consisting of organic relics." This statement is clearly an error as no limestone occurs in such stratigraphical position near the northern part of the mountains. Next is what is called a "water limestone destitute of organic relics" capped by a layer of "iron pyrites" which is evidently the waterlime. Above this is a "slaty sandlime destitute of organic relics" which apparently refers to the Tentaculite limestone, while the

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[a] Geol. of N. Y. pt 1, p. 325.
[b] Geol. surv. of the co. of Albany, p. 56.

Pentamerus, Shaly and Becraft limestones were apparently overlooked since the succeeding and highest division is described as a "porous sandstone containing organic relics" which judging from the statement that "the best locality of this rock is in the town of Berne on the height of the Helderberg"[a] is undoubtedly the Oriskany sandstone.

Next in order is the report of Mather in 1843 describing the geology of the first geological district of New York,[b] while Emmons in 1846 added materially to the knowledge of the geology of that region.[c]

In 1859 Prof. Hall enumerated the formations "comprising the Helderberg mountains proper in Albany county" and proposed the names "Lower Helderberg group" composed of the Tentaculite, Pentamerus, Delthyris shaly, Encrinal and Upper Pentamerus limestones and "Upper Helderberg group" composed of the Schoharie grit, Onondaga and Corniferous limestones.[d] It was stated that "the Lower Helderberg group...has been so termed from its very complete development along the base of the Helderberg mountains; constituting in this part of New York an important fossiliferous group.[e]

In geological classification the Upper Helderberg has been partly superseded by the term Corniferous period and series but the name Lower Helderberg series or Helderberg limestones is still generally in use.

Mr Darton has discussed recently "the relations of the Helderberg limestones and associated formations in eastern New York" and described the geology of Albany co., adding considerably to the knowledge of the stratigraphical and structural geology of the Helderbergs.[f] However on account of the absence of any detailed section in the above works the authors of the present paper decided to describe two typical sections of the eastern flank

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a Geol. surv. of the co. of Albany, p. 29. A description of the geological divisions mentioned above is given on p. 26-30.

b Geol. of N. Y. pt 1, p. 317-53.

c Agriculture of N. Y. 1:153-86.

d Geol. surv. N. Y. Paleontology, vol. 3, pt 1, p. 97.

e Ibid, p. 33. *See also* p. 33-45.

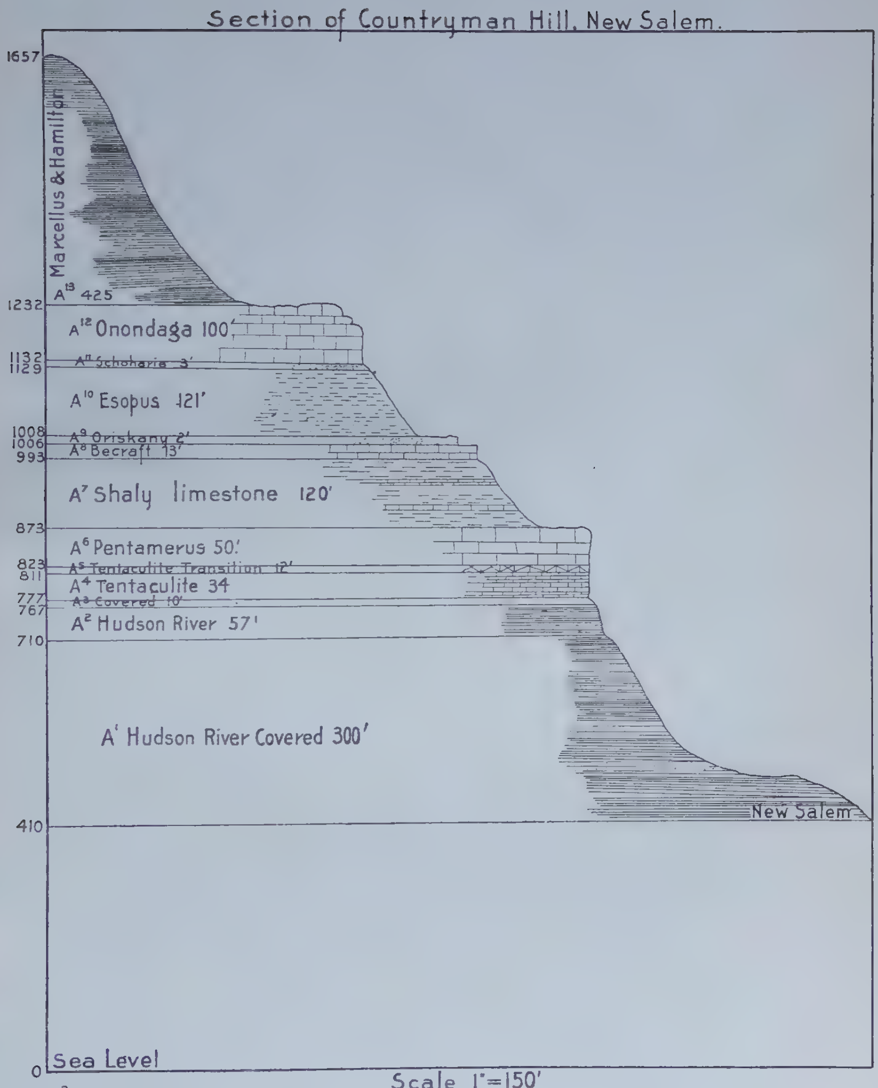
f 13th An. rept. N. Y. state geol. 1894. 1:197-261.

of the Helderbergs in New Scotland township, the first, Countryman hill from near the northern end of the Helderbergs to the west of New Salem, and the second, a few miles farther south along Onisketbau creek and in the vicinity of Clarksville. The more northerly of the two sections will be described first.

NEW SALEM AND COUNTRYMAN HILL

New Salem is a small village with less than 200 people located in the northern central part of New Scotland township at the foot of the steepest part of the Helderbergs and three miles southwest of Voorheesville, a station on both the Susquehanna division of the Delaware and Hudson and the West Shore railroads. To the west of New Salem, its base being only a short distance from the village, is the rugged slope of Countryman hill which forms the highest and most precipitous point of the Helderberg range. For two miles and a quarter to the north the lower part of the escarpment is specially marked, being composed of massive limestone cliffs which form perpendicular walls from 50 to 100 feet high and then it turns sharply to the west. New Salem is a little over 400 feet above sea level, the foot of the cliffs of Countryman hill 500 feet and its top about 1650 feet A. T. The eastern side of the hill consists of three steep cliffs which are separated by two marked terraces. The two lower cliffs are composed mainly of massive limestones between which is a terrace of shaly limestone and shale the central part of which is broken by a heavy ledge of limestone and sandstone, while the upper cliff is composed principally of shales which become arenaceous toward the top. On top of the hill it is comparatively level for several acres while to the west is a small valley formed by a branch of the Onisketbau creek, on the western side of which rises a higher ridge which forms the culminating part of the Helderbergs, its summit being given by the U. S. coast survey as 1823 feet A. T. From the top of these hills on a clear day a magnificent view of the great Hudson valley and the mountains to the east may be had, a view that well repays one for the steep ascent.

Plate 1


Section of Countryman Hill, New Salem.
1657
Marcellus & Hamilton
A13 425
1232
A12 Onondaga 100'
1132
A11 Schoharie 3'
1129
A10 Esopus 121'
1008
A9 Oriskany 2'
1006
A8 Becraft 13'
993
A7 Shaly limestone 120'
873
A6 Pentamerus 50'
823
A5 Tentaculite Transition 12'
811
A4 Tentaculite 34
777
A3 Covered 10'
767
A2 Hudson River 57'
710
A1 Hudson River Covered 300'
New Salem
410
0
Sea Level
Scale 1"=150'

About New Salem and part way up the lower cliff of Countryman hill the geological formation is the Hudson river which in general underlies all of the great plain from the Helderbergs east to the Hudson and north to the Mohawk river. The underlying rocks however for considerable areas of this plain are covered by later formations belonging both to the Glacial and Champlain. The Hudson river rocks about the foot of the Helderbergs consist of alternations of shales and sandstones that are comparatively barren in fossil remains. The only fossils reported from the Hudson river rocks of this region, so far as known to the writer, are *Orthis testudinaria* and *Trinucleus concentricus* which were found by Mr Walcott at the Indian Ladder on the northern escarpment of the Helderbergs about two and one half miles northwest of New Salem.[a] The formation has a great thickness in this region as shown by a well drilled near Altamont (formerly Knowersville) which started 595 feet below the base of Tentaculite limestone and reached the top of the Trenton limestone at a depth of 2880 feet, giving a thickness of 3475 feet for the Hudson and Utica formations to which with the exception perhaps of a few feet at the top, all the rocks in this section between the Tentaculite and Trenton limestones belong.[b]

SECTION OF COUNTRYMAN HILL

[c]XXXIX A. The following section begins at the foot of the steep cliff a little north of west of New Salem and continues to the top of the hill.

		Feet
A[13]	Top of Countryman hill composed of rather arenaceous shales that contain very few fossils. On the top are loose glacial boulders of Corniferous limestone. Near the base of this upper ridge are fine, argillaceous shales of the Marcellus shown in small draws, but the greater part of the slope is covered by soil so that it is impossible to determine	425=1247

[a]Bull. geol. soc. Am. 1890. 1:345.
[b]Ashburner. Trans. Am. inst. min. eng. 1888. 16:951-53.
[c]Union college geological survey.

		Feet
	the line of division between the Marcellus and Hamilton formations. Again in the Helderberg region there is a gradual change in the lithologic characters from the Marcellus to the Hamilton, and the Marcellus shales have a greater thickness than in central and western New York. It is probable that the upper part of the hill belongs in the Hamilton formation. To the southwest across one of the head branches of the Oniskethau creek is the highest ridge of the Helderbergs which is composed of slightly arenaceous shales containing abundant Hamilton fossils.	
A^{12}	Cliff of massive limestone, the top of which forms the upper terrace due to the erosion of the Marcellus shale. The rock is light gray in color, contains in places a considerable amount of chert and is not very fossiliferous, most of the species being corals. *Onondaga* limestone.	100=822
A^{11}	An impure, dark gray limestone which weathers to a buff, porous sandrock, shown in places at the base of the Onondaga limestone on the cliff south of west of the house of Mr K. P. Parrish, where a thickness of 2′ 10″ was measured. *Schoharie* grit.	3=722
A^{10}	Blackish, somewhat arenaceous shales which contain specimens of *Spirophyton cauda-galli* (Van.) Hall. *Esopus* shale or *Cauda-galli* grit.	121=719
A^{9}	Very dark gray quartzitic sandstone which weathers to a brownish color and contains abundant fossils. The upper surface of this sandstone is generally covered with markings of *Spirophyton cauda-galli*, and it forms the upper part of the lower terrace. *Oriskany* sandstone.	2=598
A^{8}	Ledge of massive, light gray, fossiliferous limestone which is well exposed for some distance above the highway in the vicinity of the house of Mr K. P.	13=596

Plate 2

BOULDER OF CORNIFEROUS LIMESTONE; TOP OF COUNTRYMAN HILL

		Feet
	Parrish. This limestone was formerly called the *Upper Pentamerus* but recently Prof. Hall has named it the *Becraft* limestone.[a]	
A[7]	Grayish calcareous shales and shaly limestones. The shales contain great numbers of fossils many of which are nicely preserved. This formation constitutes the lower part of the first terrace to the west of New Salem and has the most gentle slope of any of the formations composing this part of the hill until the talus at its base is reached. *Shaly* limestone.	120=583
A[6]	Massive bluish gray limestone forming the upper part of the conspicuous cliff to the west of New Salem. This limestone forms the upper part of the prominent cliff which may be followed from southwest of New Salem around the northeastern and northern ends of the Helderbergs to Altamont. An excellent idea of the massive appearance of this limestone is given in an accompanying plate the upper part of which shows the limestone as it appears on the western side of the "Indian Ladder" road at the northern end of the Helderbergs. *Pentamerus* limestone.	50=463
A[5]	Thinner bedded limestones than the above which are transitional in lithologic and faunal characters from the Pentamerus to the Tentaculite limestone.	12=413
A[4]	Dark blue thin-bedded limestones, the layers of which are generally from one to three inches in thickness and break with a ringing sound. These thin limestones form the lower part of the vertical cliff from New Salem around the northern end of the Helderbergs to Altamont. *Tentaculite* limestone.	34=401

a 13th an. rep't N. Y. state geologist, p. 212.

		Feet
A^3	Covered by soil and talus.	10=367
A^2	Bluish gray, fairly massive sandstones which alternate with dark colored argillaceous shales. *Hudson river* sandstones.	57=357
A^1	Covered by soil, drift and talus to the foot of the hill.	300=300

SECTION SOUTH OF NEW SALEM

In the above section the contact of the Hudson formation and the overlying limestones is covered, but in a small glen west of the house of Rensselaer Markel one half mile south of New Salem the contact is clearly shown. The section of this glen is as follows:

		Feet
B^6	Massive limestone forming cliff at the head of the run which is the southerly continuation of the lower cliff directly west of New Salem. *Pentamerus* limestone not giving however the entire thickness of the formation.	38=180
B^5	Transitional layers from the Pentamerus to the Tentaculite limestone, containing *Spirifer vanuxemi* Hall and *Leperditia alta* (Con.) Hall.	12½=142
B^4	Thin bedded dark blue limestone. *Tentaculite* limestone.	32½=129½
B^3	Drab, impure limestone, well exposed in the run at the foot of the cliff. These beds are shown in the accompanying plate. Waterlime.	6½=97
B^2	Greenish sandstone to coarse arenaceous shale containing plenty of iron pyrites, 10 inches in thickness. Possibly it represents the attenuated *Clinton* formation.	½[a]=90½
B^1	Dark blue to olive tinted argillaceous shales well exposed in the steep banks of the brook. *Hudson river* shales.	90=90

[a] Given at 6″ instead of 10″ for convenience in summation of section.

WATERLIME AND TENTACULITE LIMESTONE, NEW SALEM

PALEONTOLOGY

The data for the preparation of this article have been obtained while directing the work of the class of Union college in field geology and there has not been the opportunity for a thorough collection of the fossils from the different formations.

Tentaculite limestone. This limestone contains but a comparatively small number of species, and only three that occur frequently. Of these *Tentaculites gyracanthus* (Eaton) Hall is so abundant as to suggest the name for the formation. The following species were obtained:

1 *Tentaculites gyracanthus* (Eaton) Hall (aa)
2 *Spirifer vanuxemi* Hall (aa)
3 *Leperditia alta* (Con.) Hall (aa)
4 *Megambonia aviculoidea* Hall (r)
5 *Modiolopsis* (?) *dubia* Hall (r)
6 *Chaetetes* (*Monotrypella*) *arbusculus* Hall (r)

Pentamerus limestone. This limestone like the Tentaculite contains but a small number of species. The *Pentamerus galeatus* Dal., or *Sieberella galeata* as it is now called by Professors Hall and Clarke is fairly abundant and furnished the name for the formation. Below is the list of species collected:

1 *Sieberella galeata* (Dal.) H. & C.=*Pentamerus galeatus* Dal. (a)
2 *Uncinulus mutabilis* (Hall) H. & C.
3 *Atrypa reticularis* (Linn.) Dal.

Shaly limestone. This contains a larger number of species than any other formation exposed on Countryman hill and on account of the softer nature of the rocks of which it is composed, it is not so generally exposed as the other limestones of the Helderberg mountains. One of the best localities for collecting yet seen in the northern Helderberg region and the one that furnished the following species is along the highway below the house of Mr K. P. Parrish:

1 *Stropheodonta* (*Leptostrophia*) *becki* Hall (c)
2 *Spirifer perlamellosus* Hall (a)
3 *Leptaena rhomboidalis* (Wilckens) H. & C. (a)

4 *Trematospira globosa* Hall (c)
5 *Spirifer cyclopterus* Hall (c)
6 *S. macropleurus* (Con.) Hall (c)
7 *Stenoschisma formosa* (Hall) H. & C.=*Rhynchonella formosa* H. (r)
8 *Atrypa reticularis* (Linn.) Dal. (r)
9 *Meristella arcuata* Hall (r)
10 *Orthis* (*Dalmanella*) *planoconvexa* (Hall) H. & C. (r)
11 *Nucleospira ventricosa* Hall (r)
12 *Strophonella punctilifera* (Con.) H. & C. (c)

Some of these specimens seem to be the species called *S. cavumbona* H.; but it is said to be identical with *S. punctilifera* (Con.) H. & C. in *Paleontology*, vol. 8, pt 1, p. 291.

13 *Tentaculites elongatus* Hall (r)
14 *Streptelasma strictum* Hall (r)
15 *Fenestella* sp. (c)
16 *Dalamanites pleuroptyx* (Green) Hall (r)
17 Crinoid segments
18 *Uncinulus vellicatus* (Hall) H. & C.=*Rhynchonella vellicata* Hall (r)
19 *Lichenalia torta* Hall (r)
20 *Uncinulus abruptus* (Hall) H. & C.=*Rhynchonella abrupta* Hall (r)
21 *Favosites sphaericus* Hall (r)
22 *Eatonia medialis* (Van.) Hall (r)
23 *Rhynchonella transversa* Hall (?) (r)
24 *Orthoceras* sp.
25 *Trematospira multistriata* Hall (r)
26 *Avicula tenuilamellata* Hall (?) (r)

Becraft limestone. This limestone was formerly called the Upper Pentamerus on account of the abundance of *Pentamerus pseudogaleatus* Hall—now called *Sieberella pseudogaleata* by Hall and Clarke—but in 1894 Prof. Hall gave it the name Becraft limestone from its occurrence on Becraft mountain near the city of

Plate 4

BECRAFT LIMESTONE AT NEW SALEM

Hudson, Columbia co.[a] This limestone forms a conspicuous ledge near the house of Mr Parrish, the top of the shaly limestone being shown in the spring below the house. The top of the limestone is bare for some distance and numerous joints are nicely shown. This is a good locality for collecting and the following list was obtained in that vicinity:

1 *Spirifer concinnus* Hall (a)
2 *Sieberella pseudogaleata* (Hall) H. & C.=*Pentamerus pseudogaleatus* Hall (a)
3 *Atrypa reticularis* (Linn.) Dal. (a)
4 *Wilsonia ventricosa* (Hall) H. & C.=*Rhynchonella ventricosa* Hall (r)
5 *Rhynchonella (Uncinulus) nobilis* Hall (c)
6 *R.* (*U.*) *campbellana* Hall (r)
7 *Orthis (Schizophoria) multistriata* Hall (c)
8 *O.* (*Rhipidomella*) *oblata* Hall (r)
9 *Spirifer cyclopterus* Hall (?) (r)
10 *Leptaena rhomboidalis* (Wilckens) H. & C. (r)
11 *Orthothetes* cf. *woolworthana* (Hall) H. & C. (r)
12 *Aspidiocrinus scutelliformis* Hall (a)
13 *Lichenalia torta* Hall (r)
14 *Streptelasma strictum* Hall (r)
15 *Favosites sphaericus* Hall (r)
16 *Bryozoa* sp.

Oriskany sandstone. This sandstone is well exposed back of Mr Parrish's house where it rests directly on top of the massive Becraft limestone. The section differs in this respect from those on West mountain west of Schoharie where an upper shaly limestone occurs between the Becraft limestone and Oriskany sandstone. The Oriskany sandstone on Countryman hill is very fossiliferous, the following species having been collected from the ledge just west of the Parrish house:

1 *Spirifer arenosus* (Con.) Hall (a)
2 *S.* *arrectus* Hall (a)
3 *S.* *pyxidatus* Hall (r)

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[a] 13th an. rep't N. Y. state geologist, p. 212.

4 *Rensslaeria ovoides* (Eaton) Hall (c)
5 *Eatonia peculiaris* (Con.) Hall (c)
6 *Meristella lata* Hall (r)
7 *Leptocoelia flabellites* (Con.) Hall (r)
8 *Orthis (Rhipidomella) musculosa* Hall (c)
9 *Hipparionyx proximus* (Van.) H. & C. (?) (r)
Small specimens, probably young individuals
10 *Platyostoma ventricosa* Con. (r)
11 *Orbiculoidea ampla* (Hall)=*Discina grandis* (Hall) H. & C. (r)
12 *Orthis* sp. (r)
13 *Stropheodonta* cf. *magniventra* Hall (r)
14 *Platyceras nodosum* Con. (r)

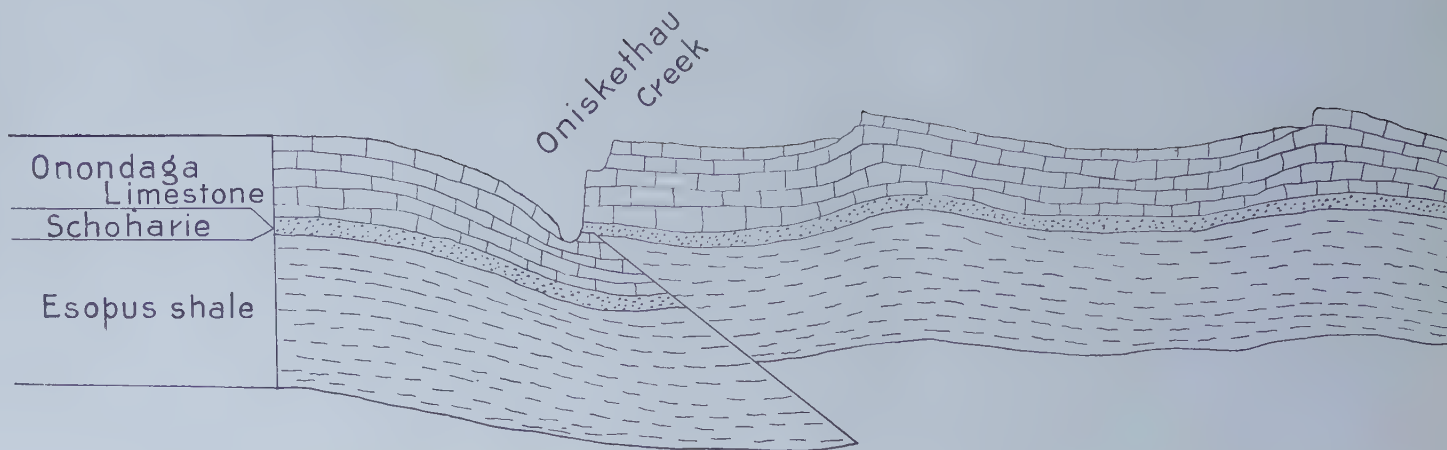
C. S. P.

CLARKSVILLE AND ONISKETHAU CREEK

Clarksville lies about 12 miles southwest of Albany on the Delaware turnpike in the southwestern part of New Scotland township. The village is in a small depression with Bennett hill on the south and Wolf hill on the west, while on the east and north is a ridge from 50 to 100 feet high. There is little doubt that this depression was at one time a lake. Onisketbau creek however long ago cut a gorge 100 feet or more deep through the ridge to the east.

The Onisketbau creek rises in the Helderberg mountains west of Wolf and Countryman hills, and flowing east between them turns southeast along the base of Wolf hill and passing through the villages of Clarksville and South Bethlehem unites with the Spraytkill to form Coeymans creek which enters the Hudson at Coeymans. At Clarksville the Onisketbau breaks through the Upper Helderberg formations making two deep and narrow gorges; one 75 or more feet deep through the Onondaga limestone just above the village, and the other which has just been mentioned through the ridge of Esopus shales east of the village. About two miles southeast of Clarksville at the saw mill of Cornelius Slingerland a less conspicuous cut is made through the shaly member of the Lower Helderberg series. At the head

Plate 5



Scale 1" = 150'

Overthrust & Folds near Clarksville.

of this cut is a fall of about 20 feet, an unusual feature in the shaly formation. The gorge is fully a quarter of a mile long and is the finest exposure of the shaly that the writer has ever seen.

There is a gorge through the Onondaga about 200 yards north of the one through which the Onisketbau now flows and somewhat smaller than it, which the writer considers to be an ancient bed of this creek. Its situation is such that the creek might easily be turned into it now and there is no other stream in the vicinity large enough to have cut such a gorge. At the lower end of the village west of the Dutch reformed church is another evidence of this ancient bed. It is a little valley running north and south, the highest part of which is not more than 10 feet above the present bed of the Onisketbau, and before the gorge was cut to the east this valley must have been the outlet to the little lake which formerly existed at Clarksville.

Along the base of Bennett hill immediately south of the village are seen the northernmost traces of these flexures which are so apparent in these formations farther south.[a] They consist of two slight folds and a small overthrust. The overthrust is in the gorge through the Onondaga above the village and may be plainly seen on its eastern side. There is a layer of Schoharie grit with Onondaga limestone dipping under it, 8 or 10 feet of the limestone being exposed, while above the Schoharie lies the regular thickness of Onondaga. A number of fissures filled with calcite, made no doubt when the overthrust occurred, may be seen in the gorge. One of the folds consisting of a broad, low anticline is very evident in the sides of the gorge through the Esopus shales below the village. The other fold is between the two gorges east of the house of Mr W. H. Rowe.

Clarksville like all the Helderberg region has been visited by many geologists. Among the first must have been Mr T. A. Conrad for he used the name Clarksville for two formations in his *Section of New York Silurian rocks*. That part of Mr Conrad's section in which this name is used is as follows:

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[a] Appalachia. 1884. 3:20-33. Plate.

20 Onondaga limestone	Atrypa nasuta, Delthyris, two species (new), Asaphas selenurus.	Wenlock limestone
19 Oriskany sandstone	Atrypa elongata, Delthyris arenosa; other large bivalves.	
18 Sandstone of Clarksville, Helderberg	A large Orthoceras, Pterinea (bilobite), Calymene platys.	
17 Limestone of Clarksville	Pileopsis tubifer.	
16 Sandstone	Fucoides cauda-galli.	
15 Blue limestone	Delthyris (new).	
14 Shaly limestone, Catskill creek	Trilobites (two new genera), Delthyris macropleura, Pileopsis ? (ventricose) Atrypa (two species), Strophomena costellata.	
13 2d Pentamerus limestone	Pentamerus (Atrypa) galeatus Atrypa lacunosa.	
12 Water limestone	Tentaculites annulatus, Delthyris (new), Orthis (new), Various univalves unnamed Cytherina, a large species.[a]	

By the foregoing quotation it will be seen that the geological formations near Clarksville were studied at least as early as 1840.

It is rather difficult to understand to which formations Mr Conrad ascribed the names "Limestones and sandstones of Clarksville," or how he came to repeat his formations in a country where the stratigraphy is so clear. The fossil *Pentamerus galeatus* establishes no. 13 as Lower Pentamerus and *Delthyris macropleura=Spirifer macropleurus* determines no. 14 as Shaly limestone. That the "Blue limestone," no. 15, is Becraft or Upper Pentamerus is proven by the following quotation from Mr Conrad: "1) a blue limestone well marked by the remains of a large species of crinoidea resembling a *Scutella* in form. 2) Oriskany

[a] Amer. jour. sci. April 1840. 38:89.

Plate 6

Falls in Onisketнau creek over Esopus shale

sandstone";[a] and a section by Mr John Gebbard which Mr Conrad quotes on the same page. No. 16 is Esopus shale or Cauda-galli grit and no. 17 is the Onondaga limestone, for *Pilcopsis tubifer*=*Platyceras dumosum*[b] is not found in any other formation except perhaps the Schoharie grit. The fossils named by Mr Conrad for no. 18, "The sandstone of Clarksville" leave no doubt that this formation is the Schoharie grit. *Calymene platys* is characteristic of the Schoharie. The Orthoceras may be any one of the numerous large species contained in this formation and it seems to be implied that *Pterinea* (*bilobite*) and *Conocardium cuneus* are the same,[c] *Conocardium cuneus* being characteristic of the Schoharie grit. The question remains why did Mr Conrad commit the error of putting the sandstone of Clarksville above the limestone instead of below it? Above the "sandstone and limestone of Clarksville," Mr Conrad placed the Oriskany, no. 19, and the Onondaga, no. 20. This may probably be explained by the fact that Mr Conrad did not recognize the Oriskany at Clarksville for it is only about one foot thick and very sparingly exposed, and if seen it might have been taken for the lower layer of the Esopus shale as the Oriskany has the same general color and the upper surface is covered with marks of the *Spirophyton cauda-galli*. And he did not correlate the limestone of Clarksville with the Onondaga limestone which is found resting on the Oriskany west of Oneida co.

Prof. Emmons in his agricultural report frequently mentions a Mr Clark of New Scotland. New Scotland as used here does not refer to the village of that name but to the township. The description which Prof. Emmons gives of the country about Mr Clark's leads the writer to believe that it was the present village of Clarksville and that the gentleman was Mr Adam Clark, from whom the place takes its name. At the time that Prof. Emmons's report was written the villages of Clarksville and New Scotland did not exist. The report contains a picture of the lower end of the gorge through the Esopus shales below the

a 3d an. rep't T. A. Conrad, palaentologist N. Y. state geol. survey, 1840. p. 203.
b *Ibid*, p. 205.
c *Ibid*, p. 207.

village of Clarksville and is labeled New Scotland but in this case also Prof. Emmons refers to the township and not to the village.

That Prof. James Hall is very familiar with Clarksville and its vicinity, a glance at vol. 6, *Palaeontology of New York* will plainly show, for a large proportion of the specimens figured in that work are listed from Clarksville and while working in that region many people were met who had known and entertained him and his assistants.

In the summer of 1892 while engaged in geologic work in this state, Mr N. H. Darton visited this region and took a picture of the gorge through the Onondaga limestone above the village.[a]

The section at Clarksville is about three miles directly south of the New Salem section. Its slopes are much more gentle than at New Salem and the ledges formed by the eroding of the softer formations are much broader.

CLARKSVILLE AND ONISKETHAU CREEK SECTION

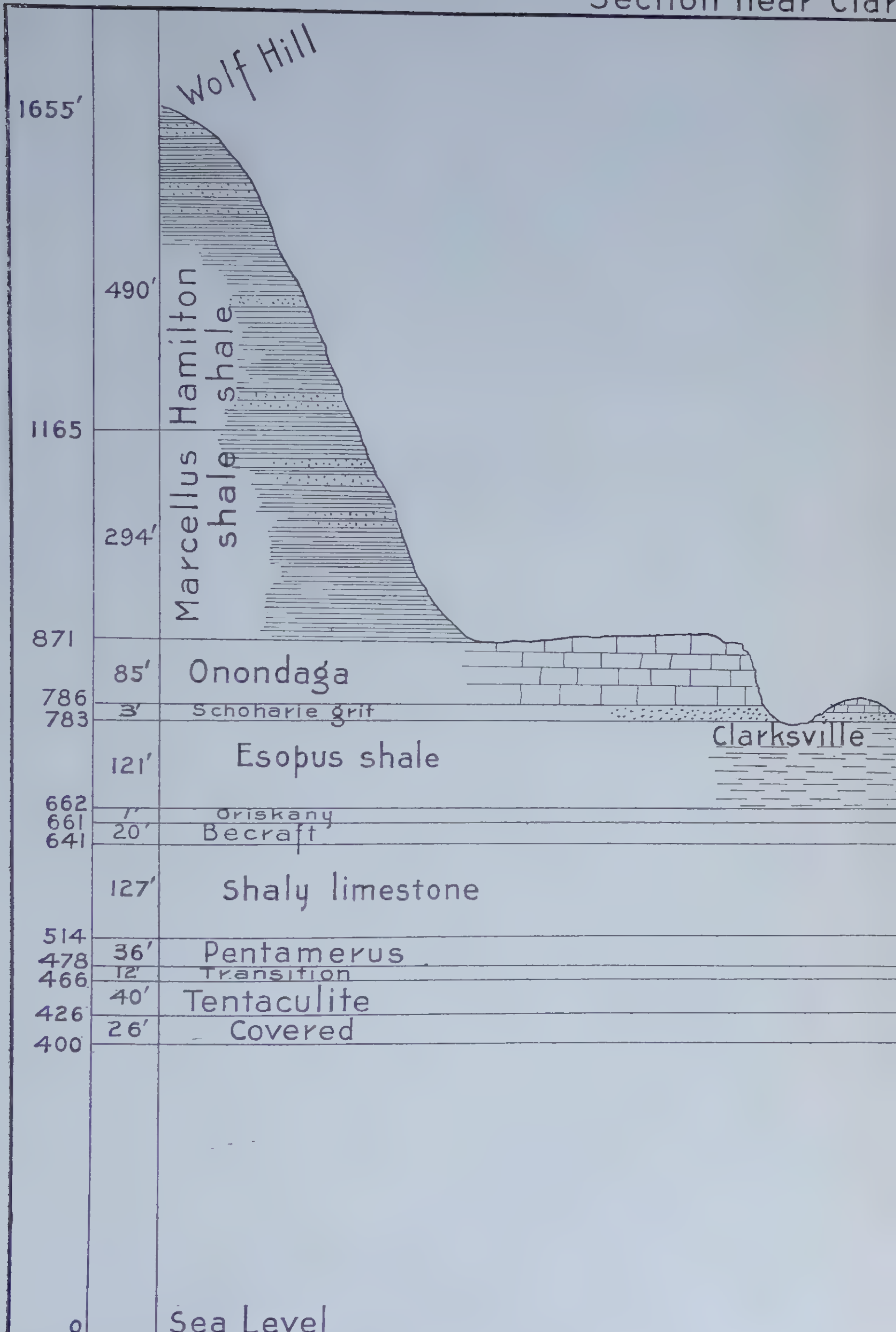
This section begins about two miles east of Clarksville near Mr Bradford Allen's about one quarter of a mile north of the Delaware turnpike and ends at the top of the Wolf hill nearly two miles west of the village.

		Feet
A^{12}	Brownish arenaceous shales and sandstones in upper part. The lower 200 feet or more of black arenaceous shales which weather to a brownish color, and brownish sandstones are well exposed in the several gullies of Wolf hill. The upper part of the hill is mostly covered though here and there ledges may be seen. About 200 feet above the base of the formation fossils begin to appear in quite large numbers and at about 400 or 450 feet they become very abundant. *Hamilton shales.*	490=1261
A^{11}	Black argillaceous shales with dark slightly calcareous sandstones. In a gully in the rear of the house of Elias Mathias the upper 200 feet of this	300+=771

a 13th an. rep't N. Y. state geol. pl. 2, facing p. 242.

Plate 7

Section near Clar



Scale 1″=200

Feet

formation are well exposed as well as its gradual transition to the arenaceous shales of the Hamilton. The lower 100 feet or more of this formation are covered, after that there are about 80 feet of black, argillaceous shales, then about 30 feet of shales of this character interspersed frequently with layers of slightly calcareous, dark sandstone above which are 85 feet of dark, argillaceous shales. It is rather difficult to distinguish the line of division between this formation and the Hamilton. At the point where the division has been made the shales suddenly become more arenaceous in character though they still retain their black color except that when exposed they weather brown. *Marcellus shales.*

A^{10} A massive gray limestone in which large quantities of chert may be found in thin layers. According to the statement of Mr H. Ingraham, who drilled a well through this formation about a quarter of a mile south of Clarksville, the upper nine feet are entirely clear of chert, below this are 15 feet in which the chert is very abundant. In the lower part of the formation chert was encountered but in rather small quantities. 85=471

There is an outlier of this formation which forms the top of the ridge east of the village, and when the Onisketbau creek cut through this ridge the outlying area was cut off from the rest of the formation. This outlier was mentioned by Mr Darton who noted the infrequency of such outliers in this formation.[a] The measurement of this formation was taken at the foot of Bennett rather than Wolf hill because the exposure there permitted it to be more accurately done. *Onondaga limestone.*

[a] 13th an. rep't N. Y. state geol. p. 242.

		Feet
A^9	A dark, impure limestone which weathers to a buff, porous sandstone. The erosion of the Onondaga limestone has left this formation well exposed at Clarksville both at the foot of the upper gorge and the top of the lower and fossils may easily be collected from it. *Schoharie grit.*	3=386
A^8	Blackish, arenaceous shales with *Spirophyton cauda-galli* (Van.) Hall. The upper five or six feet of this formation is a very heavy sandstone, somewhat calcareous, which seems to gradually pass into Schoharie grit. Only that however which contains fossils has been referred to the Schoharie. *Esopus shales or cauda-galli grit.*	121=383
A^7	A brownish black, crystalline sandstone which weathers to a light brown porous sandstone. In the creek about a mile below the village this rock is almost black and at the same distance north of it numbers of the weathered blocks may be found, while about one mile northeast of the village it forms the floor of a terrace from a quarter to a half mile in width. *Oriskany sandstone.*	1=262
A^6	A massive light gray limestone containing many fossils among which are large numbers of *Aspidocrinus scutelliformis* Hall. As this formation was not well exposed in the line of the regular section, the measurement was taken about a half mile north of it at Mr Gilbert Kniffens. *Becraft* or *Upper Pentamerus limestone.*	20=261
A^5	A gray, shaly fossiliferous limestone with occasional beds of massive limestone forming a gentle slope. On account of the shaly character of this formation a good exposure is seldom obtained. An exception to this however is mentioned on *Shaly limestone.*	127=241

Corniferous limestone overthrust at Clarksville
Fault line marked by hat

		Feet
A^4	A massive dark gray limestone which breaks into very irregular blocks. Fossils are not very plentiful and are very difficult to obtain unless the rock has been slightly burned. This formation is not as conspicuous here as it is farther north and the dividing line between it and the Shaly above is not well shown. *Pentamerus limestone.*	36=114
A^3	Limestone which in appearance and fracture is much like the *Pentamerus* but which contains a mixture of the Pentamerus and Tentaculite faunas and is transitional between these two formations.	12=78
A^2	Dark blue thin bedded limestone which breaks into almost regular blocks. *Tentaculite limestone.*	40=66
A^1	Covered by soil.	26=26

PALEONTOLOGY

The following species were collected from the various formations about Clarksville. No attempt has been made to make the number complete for any formation.

A^2 Tentaculite limestone:

1 *Tentaculites gyracanthus* (Eaton) Hall (aa)
2 *Spirifer vanuxemi* Hall (a)
3 *Stropheodonta* (*Brachyprion*) *varistriata* (Con.) H. (r)
4 *Megambonia aviculoidea* H. (?) (c)
5 *Leperditia alta* (Con.) H. (c)
6 *Chaetetes* (*Monotrypella*) *arbusculus* H. (c)

A^3 Transitional from Tentaculite to Pentamerus

1 *Leperditia alta* (Con.) Hall (aa)
2 *Spirifer vanuxemi* H. (r)
3 *Avicula communis* H. (rr)

A^4 Pentamerus limestone

1 *Sieberella galeata* (Dal.) H. & C.=*Pentamerus galeatus* (Dal.) (r)
2 *Strophonella punctulifera* (Con.) H. & C. (r)
3 *Stropheodonta* (*Brachyprion*) *varistriata* (Con.) H. & C. (r)

4	*Spirifer vanuxemi* H.	(aa)
5	*S. perlamellosus* H.	(rr)
6	*Atrypa reticularis* (Lin.) Dal.	(r)
7	*Uncinulus mutabilis* (Hall) H. & C.=*Rhynchonella mutabilis* H.	(r)
8	*Rhynchonella semiplicata* (Con.) H.	(r)
9	*Meristella laevis* H.	(rr)
10	*Orthis* (*Orthostrophia*) *strophomenoides* Hall (?)	(rr)
11	*O.* sp.	(rr)
12	*Anastrophia verneuili* (Hall) H. & C. (?)	(rr)
13	*Favosites Helderbergiae* H.	(rr)

A[5] Shaly limestone

1	*Spirifer macropleurus* (Con.) H.	(aa)
2	*S. cyclopterus* H.	(a)
3	*S. perlamellosus* H.	(r)
4	*Leptaena rhomboidalis* (Wilck.) H. & C.	(c)
5	*Leptaenisca concava* (Hall) H. & C.	(c)
6	*Stropheodonta* (*Leptostrophia*) *becki* H.	(a)
7	*S. varistriata* var. *arata* H.	(rr)
8	*Eatonia medialis* (Van.) H.	(r)
9	*E. singularis* (Van.) H.	(rr)
10	*Strophonella punctulifera* (Con.) H. & C.	(c)
11	*Orthis* (*Dalmanella*) *subcarinata* H.	(rr)
12	*O.* (*D.*) *planoconvexa* H.	(r)
13	*O.* (*D.*) *perelegans* H.	(rr)
14	*O.* (*Rhipidomella*) *oblata* H.	(rr)
15	*O.* (*Orthostrophia*) *strophomenoides* H.	(rr)
16	*Meristella laevis* (Van.) Whitfield	(r)
17	*M. bella* H. (?)	(rr)
18	*M. arcuata* (Hall) H. & C.	(rr)
19	*Atrypina imbricata* (Hall) H. & C.	(rr)
20	*Uncinulus nucleolatus* (Hall) H. & C.-*Rhynchonella nucleolata* H.	(rr)
21	*Uncinulus vellicatus* (Hall) H. & C.	(rr)
22[a]	*U. abruptus* (Hall) H. & C.	(rr)
23[a]	*U. pyramidatus* (Hall) H. & C.	(rr)

a Collected from Oniskethau creek two miles east of Clarksville.

ONISKETHAU CREEK. FALLS IN SHALY LIMESTONE AT SLINGERLAND'S MILL

24[a]	*Stenochisma formosa* (Hall) H. & C.=*Rhynchonella formosa* H.	(rr)
25[a]	*Stenochisma altiplicata* (Hall) H. & C.	(rr)
26[a]	*Orthothetes woolworthana* (Hall) H. & C.=*Strophomena woolworthana* H.	(r)
27[a]	*Coelospira concava* (Hall) H. & C.	(r)
28	*Orbiculoidea discus* (Hall) H. & C. (?)	(rr)
29	*Trematospira* sp.	(rr)
30	*Avicula communis* H.	(r)
31[a]	*Conocardium* sp.	(rr)
32	*Dalmanites pleuroptyx* (Green) H.	(c)
33[a]	*Phacops logani* Hall (?)	(rr)
34	*Platyceras* cf. *gebhardi* Con.	(rr)
35[a]	*P. ventricosum* Con.	(rr)
36[a]	*Streptelasma strictum* H.	(a)
37[a]	*Favosites sphericus* H.	(rr)
38[a]	*Chaetetes (Monotrypella) arbusculus* H.	(rr)
39[a]	*C. colliculatus* H.	(rr)
40[a]	*Tentaculites elongatus* H.	(rr)
41[a]	*Ptilodictya nebulosa* H.	(rr)
42[a]	*Fenestella* sp.	(r)
43[a]	*Lichenalia* sp.	(rr)

A[e] Becraft limestone

1	*Aspidocrinus scutelliformis* H.	(aa)
2	*Stropheodonta becki* H.	(rr)
3	*Leptaena rhomboidalis* (Wilck.) H. & C.	(rr)
4	*Spirifer concinnus* H.	(rr)
5	*Strophonella punctulifera* (Con.) H. & C.	(a)
6	*Atrypa reticularis* (Lin.) Dal.	(c)
7	*Orthis (Rhipidomella) discus* H.	(rr)
8[b]	*O. (R.* — *) oblata* H.	(r)
9[b]	*O. (Dalmanella) planoconvexa* H. (?)	(rr)
10[b]	*Orthothetes woolworthana* (Hall) H. & C.=*Strophomena woolworthana* H.	(rr)

a Collected from Oniskethau creek two miles east of Clarksville.
b Collected in the bed of the Oniskethau creek one mile east of Clarksville.

A[9] Schoharie grit

1	*Strophonella ampla* (Hall) H. & C.	(r)
2	*Atrypa reticularis* (Lin.) Dal.=*Atrypa impressa* H.	(aa)
3	*Pentamerella arata* (Con.) H.	(a)
4	*Meristella* (*Pentagonia*) *unisulcata* (Con.) H.	(rr)
5	*M.* *nasuta* (Con.) H.	(aa)
6	*Centronella glans-fagea* H.	(r)
7	*Orthis* (*Rhipidomella*) *peloris* H. (?)	(rr)
8	*O.* (*R.*) *alsus* H.	(r)
9	*O.* (*Schizophoria*) *propinqua* H. (?)	(rr)
10	*Spirifer raricostus* (Con.) H.	(r)
11	*S.* *duodenaria* H.	(rr)
12	*S.* *fimbriatus* (Con.) Bill.	(rr)
13	*Orthotetes pandora* (Bill.) H. & C.	(rr)
14	*Chonetes hemispherica* H.	(r)
15	*Cyrtina hamiltonensis* H.	(rr)
16	*Stropheodonta perplana* (Con.) H.	(rr)
17	*S.* *inaequiradiata* H.	(rr)
18	*S.* *demissa* (Con.) H.	(r)
19	*Coelospira camilla* H.	(r)
20	*Amphigenia elongata* (Van.) H.	(rr)
21	*Cypricardinia planulata* (Con.) H.	(r)
22	*Conocardium cuneus* (Con.) S. A. Miller	(c)
23	*Phacops cristata* H.	(r)
24	*Dalmanites anchiops* (Green) H.	(r)
25	*Orthoceras zeus* H. (?)	(rr)
26	" sp.	(c)
27	*Cyrtoceras* cf. *eugenium* H.	(rr)
28	*Zaphrentis* sp. (external impression)	(a)
29	*Streptelasma* sp. (external impression)	(c)

A[10] Onondaga limestone

1	*Meristella unisulcata* (Con.) H.	(r)
2	*Leptaena rhomboidalis* (Wilck.) H. & C.	(r)
3	*Atrypa reticularis* (Lin.) Dal.	(aa)

Plate 10

Esopus shale in OnisketHau creek

4	*A. spinosa* H.	(aa)
5	*Pentamerella arata* (Con.) H.	(c)
6	*Stropheodonta concava* H.	(r)
7	*S. textilis* H.	(rr)
8	*Spirifer duodenaria* H.	(a)
9	*S. macra* H. (?)	(rr)
10	*Dalmanites (Coronura) aspectans* (Con.) H.	(rr)
11	*Phacops cristata* var. *pipa* H.	(rr)
12	*Platyceras dumosum* Con.	(o)
13	*Cyrtoceras* sp.	(rr)
14	*Zaphrentis gigantea* (LeSueur) Edw. & H.	(rr)
15	*Z. corniculum* (LeSueur) Edw. & H.	(rr)
16	*Fenestella biseriata* H.	(rr)

A11 Marcellus shale

1	*Chonetes mucronatus* H.	(a)
2	*Glyptocardia speciosa* H.	(a)
3	*Coleolus tenuicinctum* H.	(r)
4	*Goniatites discoideus* H.	(c)

(collected from gorge at foot of Bennett hill).

A12 Hamilton formation

(found about 200 feet above base of Hamilton).

1	*Lingula punctata* H. (?)	(rr)
2	*Chonetes deflecta* H.	(c)
3	*Newberria claypolii* H. (?)	(rr)
4	*Pentamerella pavilionensis* H. (?)	(rr)
5	*Camarotoechia congregata* (Con.) H. & C.=*Rhynchonella congregata* (Con.) H.	(rr)

A12 Hamilton formation

(found over 400 feet above base of Hamilton).

1	*Spirifer acuminatus* (Con.) H.	(a)
2	*S. mucronatus* (Con.) Bill.	(c)
3	*Tropidoleptus carinatus* (Con.) H.	(rr)
4	*Athyris spiriferoides* (Eaton) H.	(rr)
5	*Chonetes deflecta* H.	(c)
6	*Strophalosia* cf. *truncata* (Hall) H. & C.	(r)
7	*Pterinea flabella* (Con.) H.	(r)

8	*Nyassa arguta* H.	(aa)
9	*Leptodesma rogersi* H.	(rr)
10	*Actinopteria subdecussata* H.	(rr)
11	*Liopteria dekayi* H.	(rr)
12	*L. bigsbyi* H.	(rr)
13	*Palaeoncilo maxima* (Con.) H.	(rr)
14	*P. constricta* (Con.) H.	(r)
15	*Modiomorpha concentrica* (Con.) H.	(rr)
16	*Tentaculites bellulus* H. (?)	(rr)

R. B. R.

LIMESTONES OF NEW YORK AND THEIR ECONOMIC VALUE

BY

Heinrich Ries, Ph. D.

CONTENTS

PREFACE

Limestones are used for a number of purposes but in the following report only the chemical uses of the rock, such as its applicability to the manufacture of cement, lime, paper making, etc. are considered.

Few states probably contain a greater series of limestone deposits than New York, nor is it probable that in any of them are they more favorably situated for working or more easily accessible, permitting the shipment of the rock in many cases either by rail or water. These facts considered in connection with the growing use of limestone seem to justify a detailed description of the limerocks of New York state in their economic uses, and it was with this end in view that the present report has been compiled.

While limestone is used for a number of purposes, one of its most important applications in this country is for the manufacture of portland cement and several flourishing portland cement factories are already in operation in this state.

In the course of the work a number of quarries have been visited for the purpose of obtaining samples for analysis, and about 60 analyses have been made for this report. These were made in part by the writer but generally by Messrs D. H. Newland and J. D. Irving. To these analyses have been added all those which could be obtained from other sources.

Geologic and geographic distribution of the limestone formations in New York state

The limestone formations occurring in New York state are the:

Precambrian
Calciferous
Chazy
Trenton
Clinton

Niagara
Onondaga
Lower Helderberg
Upper Helderberg
Goniatite
Tully

The most important of these are the Calciferous, Trenton, Niagara, Lower Helderberg and Upper Helderberg. The Calciferous and Niagara sometimes contain sufficient magnesia to be called true dolomites and this fact together with the freedom from impurities which they exhibit at some localities gives them a special usefulness.

Calciferous. The rock of this formation is frequently highly magnesian, and a high percentage of silica is likewise not uncommon in it. On this account it is sometimes called Calciferous sandrock.

The Calciferous limestones occur as isolated patches or belts in several portions of the state, and show considerable variation in character. With few exceptions they are magnesian and indeed may pass into true dolomites. On the other hand they are often highly siliceous, so much so as to render them practically worthless for any of the uses considered in this report. Again they may run very low in silica, as near Glens Falls.

The formation first appears in the southeastern portion of the state in Orange co. extending northeastward across the county to the Hudson river, and across it through Dutchess into Columbia co.

Another series of belts begins in Westchester co. and extends from New York city northward to the county line and through Putnam and Dutchess co. to Pawling and beyond.[a] The character of these is mentioned in the county descriptions.

Another belt of Calciferous limestone extends from Saratoga westward through Montgomery, Fulton and Herkimer counties. With the exception of the outcrops in the vicinity of Glens

[a] These Westchester limestones are probably Trenton in part.

Falls the rock in this belt is usually very siliceous and is known as sandrock.

In Herkimer, Fulton, Saratoga and Montgomery counties this formation underlies a considerable area and often forms cliffs along the rivers and creeks. Its normal character is fairly constant, viz, a light bluish gray, fine grained, massive bedded sandy limestone. The weathered surfaces are generally a dirty buff. The following localities are noted by N. H. Darton as affording good exposures:[a]

About Middleville, Littlefalls and northwestward along the fault scarp, on East Canada creek, about St Johnsville, along the Mohawk from Canajoharie to the "Noses" the quarries at Tribeshill along the Mohawk from Amsterdam to Hoffmans, also in southwestern Saratoga co. and west of Saratoga Springs.

According to Walcott[b] the section of Calciferous near Saratoga involves:

Massive layers of steel gray, more or less arenaceous limestone	125 feet
Massive bedded, slightly magnesian, gray and dove colored limestone	35
Unfossiliferous, impure, compact, more or less siliceous limestone	95
Dark gray, even bedded limestone	50
Oolitic limestone	30

Trenton. The Trenton limestones involve several different members, viz, Birdseye, Black river and Trenton, the latter being the upper one.

The most southern area is a small patch of impure, fossiliferous limestone along the river road four miles north of Newburgh.

An important belt extends southward along the Champlain valley, then along the Mohawk to Littlefalls and thence northwestward to Watertown. Beds of the same age also occur east of Lake Champlain and extend southward into Washington co.

a 13th Rep't N. Y. state geol. 1893, p. 418.
b Bull. no. 81, U. S. geol. survey, p.346.

In this latter belt they are often metamorphosed or folded, but along the lake shore, specially along the margin of the Adirondack island of crystalline rocks, the beds are little disturbed and sometimes highly fossiliferous. The Birdseye rarely exceeds six feet in thickness. It is a pure dove colored to dark gray limestone with conchoidal fracture and often containing veins of quartz or calcite.

The Black river limestone also occurs in the Champlain valley and is locally known as Isle Lamotte marble. It has a varying thickness from 35 feet on Larrabee's point to 75 feet on Crown point and 20 feet at Plattsburg. The stone is usually heavy bedded, tough, compact and black.

The Trenton proper is well exposed at Crown Point, N. Y. where it has a thickness of 150 feet. It is usually thin bedded and shaly but contains several beds of purer limestone.

Beginning at a point about one half mile south of Smiths Basin in Washington co. the Trenton limestone extends northward passing east of North Granville, east of Whitehall which lies on the western edge of the belt, then northward in a belt from one mile to half a mile wide, past Benson Landing and northward into Vermont. The town of Vergennes lies on the eastern border of the belt. Another strip of this same rock is found farther south in Washington co. extending from a point half a mile north of Easton Corners, up to and for half a mile north of Argyle. Throughout its extent the rocks of these two more or less continuous belts have been highly disturbed by dynamic forces. They are much folded and crushed and at times assume a very slaty structure. The limestone is generally fine grained and of a black color, is traversed by numerous veins of white calcite and is frequently of high purity. It is mined at Smiths Basin and also west of Fairhaven near the Vermont line.

At both of these localities the stone has been quarried for lime making and flux.

In the Mohawk valley only the Birdseye and Trenton members are present.

The Birdseye member is in greater part a fine grained, dove colored stone, and weathers light gray, and the beds are generally moderately heavy. The exposures are common in the Mohawk valley and have been quarried at a number of localities. Underlying this rock is the Calciferous sandstone.

According to Darton[a] the formation reaches its maximum thickness at Fort Plain where it is about nine feet thick. It then decreases westward to seven feet near St Johnsville. It is five feet on East Canada creek, four feet around Littlefalls and to the southeastward, and five to six feet on West Canada creek about Middleville, Newport and Cold creek.

At Ingham Mills the rock is well exposed in Butler's lime quarry. At this point nearly 15 feet of a good grade of stone is exposed. At Canajoharie the Trenton member of the group appears. Excellent exposures occur near Amsterdam and at Glens Falls. At this latter locality the quarries are of special importance. The Trenton limestone member is found extending eastward from Oneida co. to Glens Falls. At times the rock is massive as at Tribeshill, at others it is somewhat shaly. The thickness in the quarries at Tribeshill is 12 to 14 feet of massive stone. Other exposures also occur in the quarries about Amsterdam and again in quarries two miles northwest of Hoffmans where about 20 feet of a soft, highly fossiliferous limestone is exposed.

A belt of Trenton occurs west of Saratoga and is well exposed at Howland's mill three miles due west—southwest from Saratoga Springs. The section here shows 20 feet of limestone.

At Glens Falls the Trenton limestone is well exposed on both banks of the Hudson, and is of much importance, being used for building stone lime and portland cement.

Darton gives the following section of it:

Thin-bedded black limestones in beds 3 to 8 in.	10 feet
Black marble 10 to 14 in. beds.	3
Black marble 1 or 2 in. beds.	13

a 13th an. rep't N. Y. state geol. 1893, p. 422.

Black, massive, fine grained limestone. In floor of quarry	3 feet
Dark gray, fine grained limestone	25
Black, compact limestones with slaty layers	

Trenton limestone. This is found extending up the Champlain valley with a thickness of 230 feet. It overlies the Chazy. There are also extensive outcrops of it around Hoosick Falls but at this point the stone is apt to be slaty.

Quarries have been opened up in the Trenton limestone at Isle Lamotte, Plattsburg, Larabees point and Fort Frederick on Crown point.

The Trenton rocks also extend westward along the Mohawk valley and northward to Watertown. They are quarried at Prospect, Oneida, Port Leyden, Boonville and Watertown. The Trenton limestone formation is dark gray to black and is often fossiliferous.

The central part of the Trenton formation is apt to be shaly in places while the lower member known as the Birdseye limestone is massive and heavy bedded. The upper part of the Trenton formation or Trenton limestone proper is a lighter gray limestone and finely crystalline in its nature. This member is quarried at Prospect.

Chazy limestone. The Chazy limestone first appears at Saratoga and extends northward along the Champlain valley to Montreal. The area is probably a continuous one though not exposed at all points. The most prominent exposures of the Chazy are in the quarries of the Chazy marble lime co. and William Goss, and at Grand Isle. The rock is a gray, subcrystalline limestone, and affords an excellent lime. The average thickness of the formation according to Brainerd and Seely is about 700 ft. The character of the stone is quite uniform. Large quarries have also been opened in the Chazy on Willsboro point, Essex co.

The Chazy limestone is not found in the Mohawk valley and thins out in the central and western part of the state.

An analysis of the Chazy limestone from the quarry of the Chazy marble lime co. at Chazy, shows the high degree of purity of this limestone which is used in the manufacture of lime.

Silica	.72
Ferric oxid and alumina	.39
Lime	53.90
Magnesia	1.44
Carbon dioxid	43.92
	100.37

Niagara limestone. In Schoharie co. we find the eastern end of this formation. Its thickness is not more than five feet and it is usually a dark gray massive limestone. An exposure of it can be seen at Howe Cave just below the cement quarries of which it forms the floor.[a]

The Niagara limestone also appears in Oneida co. north of Clayville and extends westward with increasing width to the Niagara river.

In Wayne co. in the town of Butler[b] it is a dark blue, fine grained compact limestone and is usually thin bedded. It has been used at this point for burning lime.

Other occurrences are at Rose on the head waters of Sheldon creek and in the towns of Marion and Walworth. It has been quarried at many points in Wayne co. for the manufacture of lime.

In Monroe co. the northern edge of the limestone passes through the towns of Penfield, Brighton, Gates, Ogden and Sweden. The outcrops at these points generally represent the beds of the upper magnesian member and its weathered surface presents a characteristic spongy appearance.

The Niagara formation presents two types of lime rock. The one a dark gray subcrystalline stone which is used for lime and building purposes, the other a gray-brown, crystalline rock with numerous cavities and containing a high percentage of magnesia.

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[a] Darton's Helderberg limestones and associated formations in eastern New York. 13th an. rep't N. Y. state geol. 1893, p.218.

[b] Hall. Geol. 4th dist. p.84.

The area in which the Niagara limestone is found is more restricted than that of most of the other limestone formations of the state. The upper member of this formation is known as the Guelph limestone but is not coextensive with the lower member. It forms a lenticular bed about 20 miles long and extends from Rochester westward. In the vicinity of Rochester quarries have been opened in it at New Brighton and Gates. As exposed in these quarries it is a grayish brown, finely crystalline limestone containing numbers of small cavities. The peculiar feature of this rock is that it contains a large amount of magnesia and a very low silica percentage, making it very adaptable for use in the lining of bessemer converters.

Helderberg limestones. These include several distinct members which are known as the Tentaculite, water lime, Pentamerus, Catskill shaly, Becraft and upper shaly limestones.

The formation is a widely distributed one within the state and of considerable economic importance, containing the hydraulic limestones which are so extensively developed at Rosendale near Kingston in Ulster co. and through the western part of the state.

Its members enter the state at the southeastern corner just east of Port Jervis, New York. They then follow up the southeastern side of the valley of Neversink river, Basherkill, and Rondout creek. Throughout this whole distance the limestone rests on the Shawangunk grit which forms the crest of the Shawangunk mountain. From Kingston the same formation extends northward past Catskill to New Baltimore where it then swings to the northwest, extending as far as New Salem in Albany co. At this point it becomes very narrow but appears again as a somewhat broad belt just west of Meadowdale in the same county and then extends westward as far as Central Bridge in Schenectady co. and from there in a slightly northwest direction past Sharon Springs, Dennisons Corners, Oneida, Syracuse, and westward to Niagara Falls. Up to Dennisons Corners the formation though of considerable thickness does not cover a very broad belt owing to the perpendicular escarpment which it forms, but its thickness remains about the same from Syracuse

westward to Buffalo, and the elevation of the escarpment decreases.

As the Helderberg limestones are of considerable thickness in New York state it may be well to mention them in detail. This can be best done by quoting from the report of Mr N. H. Darton.[a]

The Helderberg limestones attain their greatest development in eastern New York, and the thickness reported by Davis of about 300 feet in the Catskill region is the maximum. They thin gradually southward in New York, but expand again in New Jersey. In the Helderberg mountains they are 200 feet and at Schoharie not over 240 feet. Westward from Schoharie the thickness decreases very gradually. The members constituting the formation in its typical development beginning at the top are, a pure semi-crystalline, massive, very fossiliferous limestone, a thick series of shaly limestone, and the basal series, thin bedded dark limestones of the Tentaculite beds. On Catskill creek a higher member of impure shaly limestone comes in above the pure, massive beds, thickens rapidly and continues southward to and through New Jersey. The Helderberg formation preserves its typical characters with some local variations in thickness to a few miles west of Cherry Valley. Then the upper limestone beds thin out and on the road from West Winfield to Litchfield in the southwestern corner of Herkimer county the Pentamerus beds lie directly under the Onondaga limestone. The upper members of the Helderberg limestones which come in again westward and are finely exposed at Oriskany Falls.[b] Here 120 feet of beds are exposed in and about the quarries, of which 50 feet are quite distinctly of the Tentaculite beds, 40 feet of gray beds in greater part of Pentamerus limestone age, but merging into the character of the lower beds, a few feet of beds with mixed Pentamerus and shaly limestone fauna and at the top 25 feet of gray subcrystalline rock containing a shaly limestone fauna. 25 miles west of Perryville, Madison co. this condition has continued, the lower members expanding apparently at the expense of the Pentamerus beds and the upper members giving place to Pentamerus beds. At this locality the Onondaga limestone was seen lying on a few feet of dark gray limestones containing Pentamerus, with a thin local intervening layer of Oriskany at one point, which gave place to a great mass of thin bedded gray limestone below.

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a Report on the relations of the Helderberg limestones and associated formations in eastern New York. 13th an. rep't N. Y. state geol. 1893, p.204.

b *See also* S. G. Williams. The westward extension of rocks of the Lower Helderberg age in New York, Amer. jour. sci. 3d series, 31:139-45; Abstract Am. ass. adv. sci. Proc. 34:235, 236; Amer. nat. 1886, 20:373.

The Salina formation which is such a prominent member of the series in central and western New York, thins rapidly eastward and is finally represented by an attenuated development of its upper members. This representative is the waterlime series which is more or less continuous through eastern New York, northern New Jersey and Pennsylvania. In the country of the Helderberg mountains it is not always recognizable and when present is often not over a yard in thickness. About Rondout and Rosendale it comprises thick beds of valuable cement rock and at Howes Cave there is also a cement bed of workable thickness.

The Onondaga limestone. This is the limestone series which is usually termed the "Corniferous" by many writers, but by others the upper member of the series is termed "Corniferous" and the lower member "Onondaga." As both members are cherty the term Gorniferous implies a contradistinction which does not exist, and it has been proposed by Prof. Hall to revive the term "Onondaga" to comprise the entire series. It is a well-known name in western New York where the beds are extensively quarried, and the formation is typically developed in the Onondaga region. As the name Salina has been finally adopted for the salt and gypsum group of the upper Silurian there need be no confusion attending the general use of "Onondaga" for the limestone as proposed.

The subdivisions of the Onondaga group gradually lose their physical and faunal characteristics in eastern New York and the formation is in greater part a bluish gray subcrystalline, massive limestone with lenticular masses of chert in courses and irregularly disseminated. Darker colors occur locally, notably in the upper beds about Peoria (West Berne) which are very dark and coarsely crystalline. The chert is predominant in the upper beds but it is usually present also in the lower beds. In places it is an inconspicuous feature but this is not often the case. Thin partings of shale occur rarely. About Saugerties the lower portion of the limestone is shaly and weathers buff. About Clarksville the lower members are very pure, free from chert and regularly bedded.

In Greene and Ulster counties particularly the outcropping edge of the formation is characterized by a fringe of very large disconnected blocks occurring at various intervals. In some cases these blocks lie several hundred yards from the edge of the outcrop.

Helderberg limestones. The members comprised under this name are the Upper shaly beds, the Scutella or Upper Pentamerus beds, the Lower shaly or Catskill shaly beds, the Pentamerus beds and the Tentaculite beds. These members preserve their distinctive characters throughout the region to which the report relates though there are occasional slight local variations.

The so-called Scutella beds are the uppermost member southward to near Catskill. They are light colored coarsely semicrystalline massive bedded, highly fossiliferous limestone blotched with calcite replacement of fossils, of which the most conspicuous is the so-called Scutella. These are the cups or pelvis of a crinoid, having a diameter in greater part from one to two inches, and the white calcite of which they consist contrasts strongly with the light bluish gray of the containing limestone. In the Schoharie region where these cups characterize the lower beds of the member, the overlying layers have been called the upper Pentamerus beds from the fossil *P. pseudogaleatus* which they contain and this name has been employed to some extent to comprise all the beds. In the eastern extension of the formation the distinction is lost. About Catskill, Davis designates the lower layers the "Encrinal" and the upper layers the "Upper Pentamerus" limestone. Owing to the inappropriateness of the name Scutella and the varying significance of the other names that have been employed, the geographic name of Becraft limestone has been suggested by Prof. Hall. The name is from Becraft mountain in Columbia co. where the rock is typically developed. The Becraft limestone has a thickness of 10 to 15 feet near Schoharie and the amount does not vary greatly eastward to the Helderberg mountains and by Clarksville, Aquetuck and Coxsackie. Thence it increases rapidly and Davis reports a thickness of 120 feet below Leeds.

the upper 10 feet consisting of impure and sandy or shaly layers. There are as Davis suggests many local slips in this section and my estimate of the thickness of the purer limestone would be about 60 feet.

"In the Rondout region the Becraft limestone is 40 feet thick and the upper shaly beds 100 to 150 feet thick. In the ridge just east of Whiteport there are 30 feet of Becraft limestone." About Rosendale and southward no exposures have been noted by Darton. "Underlying the Becraft limestone throughout are the lower shaly beds consisting of thin-bedded, impure, highly fossiliferous limestone with some shale beds." At some localities though, as for instance westward on the Foxkill above Galluppville, it is in greater part a massive, relatively pure limestone. In Greene and Ulster counties it has the character of the upper shaly beds, with a more or less slaty cleavage and outcropping in ragged ledges, in some cases closely resembling the lighter colored outcrops of the Esopus slate. Its thickness from Schoharie eastward is about 80 feet, and there and elsewhere in the great Helderberg escarpment it constitutes a steep slope between the Scutella and Oriskany shelf above the Pentamerus escarpment below. Its thickness apparently decreases somewhat in the Kingston-Rosendale region but it retains its characteristics.

The Pentamerus or lower Pentamerus are the most conspicuous members of the lower Helderberg formation. They give rise to the great escarpment which marks the eastern edge of the Helderberg formation as it passes along through central New York.

The beds are mostly hard, massive bedded and vertical jointed limestones. The rock is generally bluish gray in color but weathering imparts a lighter tint to the surface. Partings of slate occur occasionally as well as lenses of chert, specially in the east and south.

The Pentamerus limestone is a quite uniform member and its thickness does not vary greatly. "At Schoharie its thickness is between 60 and 70 feet, in the Helderbergs it is the same and a trifle more about Catskill (80 feet according to Davis), 50 feet at

Saugerties, 30 to 40 feet about Rondout, 70 to 100 feet about Rosendale, the maximum being in the ridge just northwest of the village. The Pentamerus beds are quite sharply demarked from those above and below them."

The finest exposures of the Pentamerus ledges are in the great escarpment of the Helderberg mountains near the Indian Ladder where they rise in great cliffs surmounting steep slopes to an altitude of 700 feet above the plain lying to the north and east.

The Tentaculite beds are thin bedded dark blue limestones, lying below the Pentamerus beds, and usually constituting the base of the Pentamerus escarpment or lying beneath its talus. The beds vary in thickness from an inch to a foot in greater part but two or three inches is the average.

The Tentaculite beds have a thickness of 40 feet at Howes Cave and Schoharie, somewhat less in the Helderberg mountains and from 30 to 40 feet through the Catskill and Kingston regions. In the Rosendale region the amount is less.

There are several outliers of the Helderberg limestone of which an important one is Becraft mountain.

Salina waterlime. The attenuated eastern extension of the great Salina formation is of variable character and thickness and may not be continuous throughout. Locally it consists of heavy beds of cement rock but generally it is composed of thin beds of more or less impure cement intercalated with thin bedded limestones of varying character.

The cement beds attain their greatest development around Rondout and Rosendale where they are extensively worked. The cement rock is a blue black, very fine grained, massive bedded deposit of calcareous magnesian and argillaceous materials and is of somewhat variable character and composition. The rock produces a cement of good quality only when the components bear certain relative proportions to each other. A characteristic feature of the rock is the light buff hue to which it weathers on the surface. At Rosendale there is a 21 foot bed of the cement at the base of the formation, then from 12 to 15 feet of mixed impure cement and limestone beds, then another cement bed 11 feet in thickness. Above these are the Tentaculite and Pentamerus.

These cement beds with some variations in thickness, and many in character, extend over a wide area from north of Whiteport through Rosendale to beyond High Falls, outcrop-

ping in a belt about eight miles long and two and a half wide. At High Falls there is an upper bed of cement 15 feet thick and a lower bed five feet thick separated by three feet of impure limestone. At Whiteport the upper cement bed is 12 feet thick, the lower from 15 to 20 and the intervening limestone 10 feet in thickness. How far they may extend under the overlying rocks to the westward is not known and their southern termination has not been explored. To the northeast the cement thins out rapidly and gives place to impure cements and limestones, but it thickens again rapidly in the Rondout region. At Rondout there are two cement beds, the lower one is 22 feet thick and the upper five feet thick with three feet of limestone and cement intervening. Northwest the lower cement bed thins.

Origin of limestone

Most limestones are of marine origin, few of them being freshwater deposits. They result generally from the accumulation on the ocean bottom, of the calcareous remains of marine organisms, such as the shells of mollusks, the cases of foraminifera, skeletons of corals, etc. These are sometimes plainly apparent in the limestone, but very often the shells become comminuted before settling on the ocean bottom, or they may be broken by the pressure of other material deposited on them, so that not infrequently limestones show no trace whatever of organic remains. Limestones of great purity have generally been deposited in the deeper portions of the ocean, far enough away from the shore to prevent their contamination by siliceous or argillaceous sediments brought down to the sea by rivers. The varying intermixture of such classes of material with the calcareous mud results in the formation of all grades of rock between a limestone and sandstone on one hand, and a shale on the other. A siliceous limestone is one with siliceous impurity, which if the silica predominates is called a calcareous sandstone. In the same way we may have a shaly or argillaceous limestone or a calcareous shale.

Limestone may also be formed chemically, viz, by the deposition of a calcareous deposit from waters having carbonate of lime in solution.

Composition of limestone

calcitic and consists of 56% of oxid of lime and 44% carbonic
calcite and consists of 56% of oxid of lime and 44% carbonic acid. It rarely occurs perfectly pure as the impurities seldom get below 1%; they may also increase to such an extent as to prohibit calling the rock a limestone. The impurities commonly present are silica, alumina, iron, magnesia and organic matter. Traces of sulfuric and phosphoric acid are also met with.

The silica may be present as pure quartz or combined with the alumina in the form of clay, and less frequently as an element of silicate minerals such as mica, hornblende or pyroxene.

It may practically be looked on as an inert impurity displacing so much carbonate of lime. At high temperatures however when the carbonic acid has been driven off and oxid of lime left, the silica will flux this lime with great eagerness. Alumina is usually present as clay. With an increase in the percentage of the latter limestone passes into cement rock. If present to the extent of 4% or 5% alumina is an inert impurity like silica, but when present in larger amounts it facilitates the expulsion of the carbonic acid gas. The reason for this is that clay contains chemically combined water which only passes off at a red heat or at the same time as the carbonic acid gas. This provides an atmosphere of watery vapor into which the carbonic acid gas escapes quicker than it would if passing off into gas of its own kind.

Iron and alkalies if present in appreciable quantity render the limestone more easily fusible, and may necessitate the handpicking of the burned rock to separate clinkers.

Magnesian limestones are known as dolomites when the percentage of magnesia is 20 or over. The rock may have special uses, but when in smaller amounts as 2 to 12% it is to be looked on as displacing equal quantities of carbonate of lime and for certain purposes as a deleterious impurity.

Organic matter is rarely absent in limestones and a very small amount may impart a gray or even black color to the rock.

While a total of 4% or 5% of impurities does not mean much when only a few tons a day are used, it becomes an appreciable item when the consumption of a given stone by one works is 200 or 350 tons a day.

Limestones may be divided into lime rock and cement rock. The former when burned falls to pieces in water with the evolution of heat or slakes. The latter when burned does not slake but forms a hard mass on the addition of water.

Uses of limestone

Furnace flux

This is one of the commonest uses of limestone. It is used as a flux for both lead and iron ores. In the blast-furnace the action of the limestone is to reduce the iron to its metallic state and also flux the impurities which pass off as slag.

The purer the limestone the more efficient will be its action and the cheaper its use, for it will be easily seen that the greater the percentage of impurities the more limestone will be required to do the same amount of work.

For reasons of economy blast furnace operators often use less pure but more easily and cheaply obtained limestones.

Some time ago a table was prepared by Mr J. M. Hartmann[a] giving the value of limestone containing varying amounts of silica, lime and magnesia. The basis of the calculation is magnesian limestone at 56c a ton and fuel at $3.50 a ton, both at the furnace.

[a] Mineral resources of U. S. 1883-84, p. 670.

Limestone			Magnesian Limestone													
Silica P. ct.	Lime P. ct.	Value cents	Silica P. ct.	Lime P. ct.	Magnesia P. ct.	Value cents	Silica P. ct.	Lime P. ct.	Magnesia P. ct.	Value cents	Silica P. ct.	Lime P. ct.	Magnesia P. ct.	Value cents
0	55	57	0	37	16	64	0	41	12	61	0	45	8	59
1	54	54	1	37	16	61	1	41	12	58	1	45	8	56
2	53	51	2	36	16	58	2	40	12	56	2	44	8	53
3	52	48	3	36	16	56	3	40	12	53	3	44	8	51
4	51	45	4	35	16	53	4	39	12	50	4	43	8	48
5	50	42	5	35	16	50	5	39	11	47	5	43	7	45
6	50	39	6	34	15	48	6	38	11	45	6	42	7	42
7	49	36	7	34	15	45	7	38	11	43	7	42	7	40
8	49	33	8	33	15	42	8	37	11	40	8	41	7	37
9	48	30	9	33	15	39	9	37	11	37	9	41	7	34
10	48	27	10	32	15	36	10	36	11	34	10	40	7	31
11	47	25	11	32	15	34	11	36	10	32	11	40	6	29
12	47	23	12	31	14	31	12	35	10	29	12	39	6	26
13	46	20	13	31	14	28	13	35	10	26	13	39	6	23
14	46	17	14	30	14	25	14	34	10	23	14	38	6	20
15	45	14	15	30	14	22	15	34	10	20	15	38	6	17

Limestone in excess purifies the iron from sulfur and also prevents the reduction of the silica to silicon.

Manufacture of basic steel

In the basic or Thomas Gilchrist process the furnace or bessemer converter is lined with some basic material (that is material containing little or no silica) such a magnesite or dolomite. In this country the latter specially is used. Two things are required of the dolomite, viz, it should contain as high a percentage of magnesia as possible, and it should not have over 1½ or 2% of total fluxing impurities. It is specially important that the silica percentage should be low, under ½% is possible. At high temperatures the lime or magnesia will eagerly unite with any silica present, and as this action is equivalent to corrosion of the lining, any additional percentage of silica will materially affect the life of the lining. Pure dolomites are rare and when found are not always in easily accessible localities, but in this state two different bodies of nearly pure dolomite are known, the one at Sing Sing and Tuckahoe, Westchester co. the other at Rochester, Monroe co.

For use the dolomite is first burned to the sintering point and then ground and mixed with tar or other material to hold it together and permit molding.

The lime used in basic bessemer converters likewise has to be of great purity, and the stone must be of such a nature that it will burn to a lumpy and not a powdery lime, for if the lime were added to the converter in the form of powder the strong blast would quickly eject a large portion of it.

Sulfite pulp

This is a superior grade of wood pulp which is made by the paper manufacturers. In the production of it considerable quantities of both dolomite and limestone are used. The following description has been kindly furnished to me by Mr T. A. Howard of the Vermont marble co.

The broken stone is thrown into cylinders, eight feet in diameter and 20 to 160 feet high. When the tubes are full, fumes of sulfur are led into the bottom and water allowed to trickle

down from the top. The stone thus becomes slowly dissolved and the liquor is drawn off into storage tanks. This solution is used to "cook" the wood. The latter is cut into chips one to two inches long, and put in a digester holding seven or eight cords of wood. The liquor is also introduced and the mixture heated by steam is under pressure for several hours. The sulfite of lime or magnesia removes all the pitch and everything except the wood fibres, and at the same time removes all discoloration.

Some manufacturers claim that the liquor can be made faster and stronger by the use of dolomite, and in order to get it they sometimes go 10 or 12 miles from a railroad. When limestone is used the cylinders generally seem to be made higher.

Lithographing

Lithographic limestone is a somewhat impure, very fine and even grained limestone. It is not only rare but valuable. The requirements are sufficient porosity to absorb ink and softness enough to permit working with an engraver's tool.

The chief supply thus far has come from Solenhofen, Bavaria. It has been reported from various localities in this country but never from New York state.

Carbonic acid gas

Considerable nearly pure dolomite has for some time been shipped from the quarries at Pleasantville, Westchester co. N. Y. for the use of soda water manufacturers. The stone is ground at the mines almost to the fineness of granulated sugar. From the grinder it passes into hoppers whence it is fed automatically through tubes into barrels for shipment.

Lime

When limestone is burned, that is when it is raised to a red heat, it is dissociated into lime oxid and carbonic acid thus:

$CaCO_3$	=	CaO	+	CO_2
limestone or lime carbonate		lime oxid quick lime caustic lime		carbonic acid gas carbon dioxid

The carbonic acid gas passes off and the oxid of lime remains behind as a white powdery or lumpy substance but may be more or less colored if iron is present.

As limestone varies in composition the lime will also but the percentage of impurities in the lime will be nearly twice what they were in the limestone for the latter has lost 46% of carbonic acid gas.

Depending on the amount and nature of the impurities present we may divide natural and artificial limes suitable for mortar into five classes:[a]

1 Common or fat-limes
2 Poor or meager limes
3 Hydraulic limes
4 Hydraulic cements
5 Natural pozzuolanas

The common or fat limes contain less than 10% impurities, and a portion of the latter are insoluble in water, all the rest of the lime being soluble. They do not harden under water but crumble or slake and increase in volume sometimes threefold. They shrink in hardening and to prevent this sand must be added.

Poor or meager limes have from 10 to 25% of impurities or sometimes even 39%.

Hydraulic limes are of three kinds:

1 Slightly hydraulic ones with 10 to 20% of impurities.
2 Hydraulic limes with 17 to 24% impurities
3 Eminently hydraulic limes with 20 to 35% of impurities.

All hydraulic limes harden under water. *Hydraulic cement* is an artificial product. It has less lime than the other classes, but not under 29%.

Natural puzzuolanas are rocks of igneous origin. They possess hydraulicity and generally contain less than 10% of lime.

It is of course possible to find all intermediate grades between limes and cements.

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[a] Gilmore. On limes, hydraulic cements and mortars, p. 69.

Slaking. When lime is placed in water the oxid unites with the water and hydroxid of lime is formed. This is accompanied by the evolution of heat and an increase in volume. Fat limes slake very fast and produce more heat than lean ones. Lime will slake even in the air by the absorption of moisture. If not used immediately it should therefore be protected from the atmosphere as much as possible.

Lime may be slaked by putting the lumps in water for a few minutes and then withdrawn and packed away to allow the lime to change to powder. The common method usually employed in building operations is to mix the lime with water in a box. Too much water makes it thin and injures its cohesive strength. If the water is added in part and the rest later, the lime becomes granular and lumpy.

After slaking sand is added to the lime to make mortar. According to Gilmore[a] the lime forms both silicate, carbonate and hydrate, and the crystals of these compounds interlock with the sand grains, thus binding the whole together into a solid mass. In the course of time all the lime changes to carbonate, but this change may take a number of years.

Slaked lime is used for a variety of purposes. Its chief use is for mortar. Quicklime is a very strong base; it displaces carbonates of the alkalies and serves therefore for the manufacture of caustic of potash and caustic soda. It precipitates magnesia from solutions of salts, and has a use in the manufacture of ammonia from ammonium chlorid. With chlorin it forms chlorid of lime, and with other acids various salts of lime. In the manufacture of illuminating gas it serves to purify the gases from carbonic acid and hydrogen sulfid. It is used in the manufacture of soda and in the extraction of sugar from beet juice. In candle manufacture it is used to saponify the fats, in tanning to remove the hair from the hides, in bleaching, and in dyeing, as a disinfectant; it is also used to treat cryolite in the manufacture of alum and in the production of fertilizers.

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[a] On limes, hydraulic cements and mortars, p. 299.

For the manufacture of lime many different types of limerocks are available, those only being excluded which are contaminated with clay, for this latter substance often affects their most important properties. It is only in later years that the applicability of limestone with a large amount of clay has been recognized.

The lime made from pure or nearly pure limestone may be called air-lime in contradistinction to hydraulic lime made from aluminous or clayey limestones.

As before stated pure limestone consists of 56% of oxid of lime (CaO) and 44% of carbonic acid. The change from carbonate of lime to oxid of lime occurs during the burning, the carbonic acid being driven off at a higher temperature. In this process the lime loses about 44% by weight.

As it is generally in a somewhat moist condition when it is put into the kiln, due to water in its pores, the loss in weight may be still greater than mentioned above.

The percentage of moisture in limestone is very variable and depends largely on the hardness and density of the rock. The denser a limestone the less porous it will be and the lower will be the percentage of quarry moisture in it.

The looser or more spongy it is the more moisture will it absorb. Marl or chalk may be looked on as the loosest form of limestone and in them the moisture may reach 36% or 40%, and in marls and bituminous limestones the loss in burning may be still farther increased by driving off organic matter.

A dense limestone is much harder to burn than a loose grained one, and requires more fuel, but this increased consumption is more than made up for by the quality of the lime obtained.

In a clean, dense limestone the percentage of quicklime may be 54% while in a bituminous one it may only amount to 30 or 35%.

In addition to the decrease in weight in burning the limestone also decreases somewhat in volume as much as 12 to 21% but usually 16 to 18%.[a]

[a] C. Schoch. Die Aufbereitung der Mörtel-materialien, p. 57.

In burning it is important to observe that the temperature remains as constant as possible and varies only between certain limits. When limestone is overburned, the lime made from it slakes slowly and incompletely. In the case of limerock with clayey impurities a sintering is very apt to occur and this should in all cases be strictly avoided.

It is true that the higher the temperature is within the permissible limits the denser will be the lime. On the other hand the temperature must not get too low, as in this case any large pieces of limestone that may be in the kiln will not become thoroughly burned. The unburned core resulting from underburning makes the lime lean. To avoid such an occurrence as far as possible it is advisable not to put too large pieces into the kiln.

The burning should proceed as rapidly as possible for if the limestone is subjected too long to the highest heat of the kiln the lime will be of inferior quality and will slake more slowly.

Limestone begins to lose its carbonic acid gas at about 750° F. but all of it does not pass off probably till the temperature of 1300° to 1400° F. is reached.

Limestone should never be burned with a coal running high in sulfur as the latter unites readily with the lime forming calcium sulfate.

This sulfate of lime reacts subsequently with the aid of moisture on any alkalies that may be present, with the formation of alkaline sulfates, which being soluble are often brought to the surface after the lime is in the wall and cause the unsightly white coatings on bricks.

The lime thus obtained by the burning of limestone is a white, amorphous, more or less dense mass with a specific gravity of 3.09. It is infusible. Lime weighs from 1400 to 1800 lb. a cubic meter, the variation in weight depending on the density of the original rock and the degree to which it has been burned. Dense stone gives a denser lime.

Quicklime is a strong base and absorbs water with the greatest avidity. In water it forms a milky liquid known as milk of lime.

Lime in its normal condition and when dry is totally unaffected by carbonic acid gas but when heated takes it up rather quickly. The addition of water to lime can be done in a variety of ways according to the degree of slaking that is to be brought about.

If a lump of quicklime is immersed in water for an instant it saturates itself at once with the former, and this absorption is accompanied by the evolution of heat, a swelling and bursting of the lime, and the latter finally falls to a fine powder, the hydrate of lime $Ca(OH)^2$. The chemical action which has taken place is expressed by the following formula.

$$CaO + H_2O = Ca(OH)_2$$

This method of hydration is considered to be better than pouring the water on the lime.

The hydrate of lime thus obtained is a fine white powder of a specific gravity of 2.1. Its water of hydration is pretty firmly combined and is only driven off by reheating to redness.

On the other hand quicklime can be made by adding the lumps of lime piece by piece to the water till a strong paste is formed by stirring the mass. The stirring is specially necessary in the case of lean limes.

In order to assist the slaking of such lean limes it has been found advisable to use only one third the necessary amount of water at first and add the other two thirds later on. Again, as the lean lime gives out much less heat it is well to keep the mixing pan covered in order to prevent its escaping. Lean lime also slakes better if a certain amount of fat lime is worked in with it. The latter has a sort of contact effect on the former, which is effective and rapid. This method is a good one to follow in using overburned lime.

An excess of water in slaking is undesirable, as it only tends to lower the temperature of the mixture. It is sometimes desirable to use hot water.

The hydration of lime powder or slaking to a pasty mass must be carried out very carefully, as otherwise, specially in the case of overburned lime, some unslaked particles will remain, which may slake later and make themselves unpleasantly prominent.

During the slaking process the lime absorbs a large quantity of water. It swells up and gradually forms a stiff paste, the more so, the purer the limestone and the fatter the lime.

With careful slacking, 1 cubic meter of fat lime gives 2.7 cubic meters and 1 cubic meter of lean lime gives 1.8 cubic meters of paste.

The excess of water is gotten rid of in part by evaporation and is also drawn off while the slaked, pasty mass is allowed to stand in the pit to insure thorough slaking of every particle.

In the pits lime will hold itself for a long time without change provided it is properly protected from the air.

The damp lime paste absorbs carbonic acid greedily with the formation of carbonate of lime, which solidifies. The crust of calcium carbonate which forms is very thin but it prevents the action from continuing farther in the mass.

The solidifying action of the lime alone is of little importance and becomes of value only when sand is added. The use of the sand prevents large masses or lumps of the lime from collecting in any one spot and not becoming thoroughly converted into the carbonate.

USES OF LIME

Sugar manufacture. Much lime is used in the manufacture of beet sugar and here again the raw material must be of the proper composition. Both clay and sand are injurious impurities as they increase the loss in lime in making the limewater and the clay also introduces alkalies into the sugar juice. The sugar manufacturer considers that every part of insoluble matter means a loss of three to four parts of carbonate of lime. When therefore a limestone containing 95% carbonate of lime is paid for as if containing 100%, a stone with 85% should only be paid for as if containing 60 to 70%. If the lime is to be used for separation the presence of much magnesia is injurious for the reason that it will not unite with the sugar as the lime does, forming a monosaccharate of lime which is essential before precipitation takes place. Consequently a large amount of magnesia hydrate in the lime necessitates the use of so much more of the latter and may also cause loss in sugar.

A limestone to be used in sugar manufacture must not have more than 25% alkalies.

The following are analyses of limes used by German beet sugar manufactures. (Thonindustrie *Zeitung*, 1897 p. 1165)

	CaO	Al_2O_3 Fe_2O_3	MgO	K_2O Na_2O	H_2S	SO_3
Limhamn, Sweden....	95.60	1.62	.79	.03		
Plymouth, Eng.......	95.22	2.44				
Gogolin, Ger. (?)......	89.82	7.28	1.04	.03		
Gr. Kunzendorf, Ger..	96.66	1.10	.86	.05		
Ober-Kauffung, Ger...	97.72	1.20	.70	.06		.15
Kösen, Ger..........	97.00	1.52	.92	.01		
Osterwiek...........	93.06	5.8				tr
Lauffen.............	90.12	7.60	2.19	.03		
Atzendorf...........	89.04	8.80	1.24	.05	much	much
Borne...............	78.24	13.00	2.24	.06		
Rüdersdorf..........	94.76	2.00	.74	.03		

It will be noticed from the above analyses that in most of the samples the percentage of lime is over 90% though in some it is under 80%. Another noticeable feature is the low percentage of both magnesia and alkalies, specially the latter. One shows the presence of much H_2S and another of appreciable amounts of SO_3.

It is the custom for beet sugar manufacturers to burn their own lime for the reason that the carbon dioxid gas is also used in the process.

For the production of the best results it is therefore important that the limestone should be of proper quality and the burning conducted in the right manner.

Silica is a deleterious impurity as it not only causes the stone to fuse but also lowers the amount of lime and carbon dioxid produced from each ton of stone used. This latter point is of course true with regard to any other impurities which may be present.

Too little fuel should also be avoided as it decreases the amount of CO_2 produced.

The stone used should be compact and hard. An excess of moisture, as 5% or over, should not be present as it reduces the temperature of the kiln when first charged. Stone containing an excess of moisture also tends to split in burning. About 1% of water is the proper amount.

Magnesia is not specially objectionable except when silicates are present in the stone; it causes difficulities however in the purification of the sugar juice, consequently it should be at a minimum. Sulfate of lime may act the same as magnesia.

If silica is present part of it passes into the juice with the lime and retards the filtration process by coating the cloths in the filter press. Silica also forms part of the scale on the heating surface. There is less harm from this source in hard than in soft stones.

Silica and alumina also tend to form an insoluble coating on the burned lumps which interferes with the slaking.

The following analyses together with most of the above information on the stones used are from the report on the beet sugar industry of the United States, dep't agriculture 1897 p. 205.

	1	2	3	4	5	6	7	8	9	10
Moisture	4.10	5.10	7.25	4.15	4.17	6.25	5.16	.52	1.21	.11
Insoluble	4.50	5.15	4.90	2.15	3.07	3.17	2.25	2.85	.55	.27
Organic matter	1.20	1.17	1.37	1.05	.97	1.12	.86	.30	.41	.15
Soluble silica	2.10	1.75	3.30	1.05	.98	.64	.56	.06	.20	.03
Iron and alumina oxid	.37	.41	.27	.17	.19	.15	.20	.32	.23	......
Lime carbonate	85.86	85.12	81.67	90.13	88.65	87.93	90.03	93.80	96.58	99.10
Magnesia carbonate	.95	.47	.59	.75	.95	.50	.45	1.81	.50	......
Alkalies	.05	.06	....	.10	.01	....	....	....	....	......
Undetermined	.87	.77	.65	.45	1.00	.24	.39	.34	.32	.34

Of the above nos. 1, 2, 3 and 4 are considered bad; 5, 6 and 7 are passable; 8, 9, 10 are excellent.

No. 3 was used in a sugar factory and caused trouble, notably "scaffolding" or difficulty in the mechanical filters. No. 9 was substituted and these difficulties disappeared.

In looking over the analyses of limestones given in this report it will be observed that limestones of as great purity as nos. 8, 9 and 10 in the foregoing table are not uncommon in New York state. There are at present two beet sugar factories in New York state, the one at Binghamton and the other at Rome.

The following are some additional analyses of limestones used in beet sugar manufacture. Nos. 1 and 2 of stone used at Los Alamitas, Cal. and no. 3, a French stone.

No. 1, the Colton stone, is good

No. 2, Oro Grande, is passable

No. 3 is bad.

	1	2	3
Lime carbonate	98.000	94.306	81.67
Magnesium carbonate	.453	1.845	2.50
Iron and alumina oxid	1.096	.929	.27
Silica, sand, etc	.281	.900	8.20
Moisture	.051	.038	5.25
Organic matter and magnesium sulfate	......	.701	1.37
Undetermined	.116	1.281	.64

Chlorid of lime. Lime which is to be used for the manufacture of chlorid of lime must be very clean for on this hangs the possibility of making a strong and stable chlorid. To satisfy these requirements the limestone must be sufficiently pure and burned as well as possible. For this reason many manufacturers purchase the limestone and burn it themselves. The burned lime should be free from carbonate of lime, and the limestone should have a minimum amount of sand, clay or similar impurities, which in burning do not of course turn into lime. Aluminous limestone clears with difficulty when dissolved and hence is not liked by bleachers and paper manufacturers.

As the consumers require a pure white lime the stone must contain practically no manganese or iron. These metals are also thought by some to injure its stability, but this point is not definitely proved. The presence of magnesia is also undesirable as the greater deliquescence of the magnesium chlorid renders the lime chlorid less stable.

The presence of organic or bituminous substances in the limestone is entirely harmless as they do little more than impart a dark color to the stone and pass off in burning.[a]

[a] Wagner. Chemische technische Untersuchung's-methoden, 1893, p.430.

Fat limes which slake quickly and fall easily to a fine light powder absorb chlorin much quicker than lean limes, which on slaking give a sandy powder even when analysis points out each as almost pure and shows no difference. In addition chlorid of lime made from fat lime keeps much better than when made from lean lime (Wright, Chem. news, 16:426)

Glass making

According to Mr J. D. Weeks[a] lime is of considerable importance in glass manufacture. "Glass rich in lime requires a higher temperature to melt and because of this is more destructive to the pots, but used in proper proportions it promotes the fusion, aids in the decomposition of the materials, and improves the quality of the glass. Lime glass can not compete with lead glass in brilliancy, but it is harder, not so easily scratched, holds its polish longer, is more elastic and consequently tougher, will stand higher temperature, resists the action of water and chemical agents and is much more cheaply produced. Lime glass also on account of the slight difference in specific gravity of the two substances composing it is less liable to become striated. In the manufacture of plate glass, which is ground and polished, it is found that glass which is rich in lime is harder to polish than that poor in lime, but it holds its polish better and longer." It may devitrify from the presence of excess of lime, as when an excess of lead or sand is used. The lime should be as free from impurities as possible, specially oxid of iron.

Below are given two analyses, no. 1 from Blair co. Pa. and no. 2 from Sandusky, O. The former is used for window glass, the latter for lime flint glass.

	1	2
Organic matter	.09	.05
Silica	1.01	1.00
Alumina	.02	.40
Ferric carbonate	.165	.....
Magnesium carbonate	1.48	41.43
Lime carbonate	97.23	56.60
Ferric oxid		.12
Moisture		.40

[a] Mineral resources of U. S. 1883-84, p. 968.

Mortar

The use of lime as a mortar has been known for many years, and the ancients were familiar with the fact that by means of simply burning limestone and soaking the burnt mass in water they could obtain a stiff paste which possessed valuable properties.

Lime is extensively utilized for mortar making at the present day.

Pure CaO has 71.4% Ca and 28.6% O. It is a porous, earthy, white solid, which when pure resists a high degree of heat. It absorbs both moisture and carbonic acid from the air with the greatest avidity.

Richardson gives the following requirements for caustic lime used for mortar.[a]

Except when made from coarsely crystalline marble or from marl or shells it should be in hard lumps.

It should be white, or nearly so, in color. Lime of a yellow or brownish color with veins of siliceous matter is inferior.

It should be free from fused or semi-fused stone which shows over burning, and from unburnt ash of fuel or clinker.

It should contain less than 10% of impurities but often has more.

It should slake rapidly, showing that it is rich and fresh.

Good lime in lumps should weigh, as packed, with about 40% of voids, 60 lb. a cubic foot, 75 lb. a bushel and from 220 to 230 lb. a bbl. of 3 bushels. If ground or in powder it will weigh less when packed loosely, but when well shaken down it will weigh as much as 270 lb. a bbl. A lump of hard lime 1 foot cube would weigh about 95 lb. having a density of 1.52.

Slaking

Lime combines with water with evolution of heat, and every 100 parts lime take 32 parts of water.

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[a] Brickbuilder, 1897, p. 78.

If 33% of its weight in water is sprinkled on lime it heats, cracks open and falls to powder.

The increase in volume in slaking is caused by the expansive force of the steam. Lime may be slaked without increasing its volume by passing dry steam over it in a tube.

The energy of slaking increases with the decrease of impurities. The same lime may show a varying increase in volume in slaking due to amount of water added, etc. The slow addition of water raises less heat. Slaking lime in an open box gives less heat than in a closed one.

With an equal volume of water the increase in size of a rich lime is 2% to 2.4%.

Richardson illustrates this point as follows:

Vol. of H_2O	Increase in volume
½	1.6
1	2.0
2½	2.5
With a poor dolomitic lime it was	
2	1.7

No set rule can therefore be laid down. For instance 1 peck lump lime with 44% of voids, on slaking with its own volume of water gave 2¼ pecks of fine powder of slaked lime.

From 1 peck of closely packed lime, 2.5 volumes of slaked lime were obtained.

Gilmore found large increases, some running 2.46, 2.83, 3.21, 2.40, but this was caused by his using larger amounts of water than are generally taken in practice.

The following table gives the tests made by both Gilmore and Richardson.

	Rockland Gilmore	Rondout	New York Richardson
Weight of lime in lb..................	5	5	5
Vol. of lime in c. c..................	1557	1806	2350
Vol. of water required to slake........	2983	3300	2000
Increase of weight in %...............	2.24	2.24	1.60
Increase in volume..................	2.46	2.14	1.91

The theoretic increase is 1.53. Lime also slakes simply on exposure to the air but it is not good for mortar making as its slaking has been accompanied without any violent disengagement of heat to rupture the mass.

The larger particles also have a hardened rim.

Method of slaking. The water may be sprinkled over the lime gradually, or added at once in excess.

The former is best because a looser mass is obtained, and it gives better results with poorer limes, slaking them more thoroughly.

Too great an excess of water tends to lower the temperature and render the slaking incomplete. This latter causes unslaked particles to get into mortar, and by their subsequent slow hydration and expansion they may do much harm. Popping of mortar is due to this cause. It is also true that if the water is added gradually it may allow the mass to cool down. Enough water should be added to allow for that escaping as steam. With very fat lime 2½ volumes of water may be taken. Poor magnesian limes take less.

Pure water should be used. That with soluble salts gives rise to efflorescence. Hence sea water can not be used though it has been successfully tried for hydraulic cement.

An excess of water gives granular paste and also makes the mortar porous.

In making mortar the sand is added to lime for economy and to prevent shrinkage. Sand should be clean and sharp and should be in such quantity that the lime will fill all the interstices. If an excess of sand is used the bond is poor. If too little sand is used the mortar shrinks and cracks. If too little lime is used the paste is made thin. In ordinary sands the spaces from 30 to 40% of the total volume and in such 1 vol. paste fills voids of 2½ vols. sand (*Brickbuilder* p. 101, 1897). In practice 1.25 to 2 vols. of sand to one of paste is used. This in case of fat lime means 3 to 5 vols. of sand to one measured vol. of lime and this gives a plastic mortar which does not crack.

Richardson gives following mortar experiments.

Composition and physical properties of the lime

Loss on ignition, H_2O and S	1.0
Insol. SiO_2 and silicates	1.2
Al_2O_3 and Fe_2O_3	.8
MgO	.6
CaO	95.6
	99.2

Weight of cubic feet including voids	60 lb
Voids	44%
Density of lump	1.52

No. of experiment	1	2	3	4	5
Weight of CaO used	1,000	1,000	1,000	1,000	1,000
Weight of H_2O to slake	1,000	2,000	2,500	3,000	4,000
Weight of H_2O for paste	1,000	500	None	None	None
Volume of H_2O to one of CaO	2	2.5	2.5	3	4
Volume of paste	2,000	2,560	2,712	3,120	4,120
Weight of paste	2,720	3,280	3,392	3,880	4,850
Density of paste	1.36	1.28	1.25	1.24	1.17
Characteristics of paste	Thick	Thick	Medium	Thin	Very thin
Volume of sand, moist	2,000	3,000	5,000	7,100	14,360
Weight of sand	3,000	4,500	7,500	10,800	20,600
Volume of sand to lime	2	3	5	7.1	14.4
Volume of sand to paste	1	1.2	1.8	2.6	3.5
Volume of mortar	3,320	4,400	5,840	7,200	13,500
Weight of mortar	5,740	7,760	10,650	13,960	25,450
Density of mortar	1.73	1.75	1.82	1.94	1.88
Consistency of mortar	Thick	Medium	Medium	Sloppy	Very sl'py
Dries	Cracks	Dries without shrinking			

Percentage composition

Water	30.00	29.30	22.50	20.70	15.1
Sand	52.60	67.90	68.10	72.20	82.0
Lime	17.40	12.80	9.40	7.10	3.9
	100.00	100.00	100.00	100.00	100.00
Return of water to lime	1.7	2.3	2.4	2.90	3.9

Cements

The name cement was formerly applied only to materials which were added to lime mortar in order to make it harden under water. Subsequently this term was used for all combined material which gave a mortar that hardened under water, and so has extended to our natural and portland cement. Cement materials

are now classed as hydraulic agents, hydraulic limes, slag cements, natural cements and portland cements. Hydraulic agents are materials which cause silica and clay to unite with the lime of common mortar, giving us a combination of slow hardening. Such hydraulic agents may be natural or they may be artificial. The natural ones are represented by the pozzuolana of Italy, and the trass of the Rhine valley in Germany. In this country they are only known in the far west. The artificial hydraulic agents include slag, burned clay, shales, ashes, silicate of soda or any inorganic material that contains clay and silica in a form permitting its solution in acids.

Hydraulic limes

Schoch divides these into three classes:

True hydraulic limes. These contain over 70% of lime carbonate

2 Roman cements, with 50% to 70% of lime carbonates

3 Dolomitic cements or magnesian cements

1 *Hydraulic lime.* When the clayey impurities increase in ordinary quicklime, it assumes hydraulic properties and the lime is known as hydraulic. Sand is an impurity which is not too large to prevent its slaking but simply retards this operation. Hydraulic limes with only 5 to 15% of silicates will harden in from 8 to 20 days, but with a larger amount in from one to four days. No sharp line can be drawn between pure cements and hydraulic limes.

True hydraulic limes generally have 18 to 25% of clay, free silicia and combined silica, iron oxid and alumina, sometimes magnesia and alkalies.

The burning of hydraulic lime must be carried on very slowly. The higher the percentage of total silicates, the lower must be the temperature of burning for under no circumstances should the material be allowed to sinter as it does in the case of portland cement. Such overburned pieces slake very slowly. Furthermore the burning should only go to the point of driving off the

CO_2. The best hydraulic lime known is the celebrated Chaux du Theil whose composition according to Dr Michaelis is

Silica	22.588
Alumina	2.629
Iron oxid	.837
Lime	65.624
Magnesia	1.536
Potash	.124
Soda	.065
Sulfuric acid	.523
Ignition	6.424

Hydraulic limes generally have a yellow color. Their specific gravity is about 2.9 and on ignition they lose about 8%. They harden slowly and by themselves their hardness is small. On the other hand if mixed with sand they get a high degree of tensile strength.

2 *Roman cement.* This is also a natural product and of the hydraulic limes has the highest silica percentage. In addition the roman cement always has a certain percentage of free quicklime which among other things distinguishes it from portland cement. The following analysis of roman cement will serve as a type (Schoch p. 74)

Silica	25.00
Alumina	9.00
Ferric oxid	4.39
Lime	58.02
Magnesia	1.08
Alkalies	.62

The ultimate composition approaches somewhat that of portland cement. The burning of roman cement must never exceed a certain temperature, in order to prevent sintering, but while the hydraulic lime naturally slakes in water the roman cement must as in the case of portland be ground to the finest of flour. Burned and ground roman cement is generally a light, yellow powder with a specific gravity of 2.7. The time of hardening varies but it is quite rapid. In mixing it with water it

does not evolve much heat. The tensile strength can be greatly increased by the addition of sand, even more so than in the case of hydraulic lime.

3 *Dolomitic cements.* These are made from magnesian limestone and are to be looked on as only a variety of roman cement, and indeed they are sometimes sold under that name. The dolomites have 54.3 of lime carbonate and 45.7 of magnesia carbonate. Other impurities are frequently present. Dolomites are found in many parts of the world, Germany, Scotland, Russia, Belgium and America. Such cements must be heated to a temperature only sufficient to drive the CO off from the magnesia. It should not as a rule exceed 400 C. If they are burned too hard quicklime is formed, which will not develop hydraulic properties except in those materials containing clay in large amounts. The quicklime in this case will form hydraulic compounds by uniting with the silicates and these do not expand noticeably in the water. Dolomitic cements do not develop much heat on mixing with water. Their tensile strength alone as well as when mixed with sand is intermediate between true hydraulic lime and roman cement.

The Rosendale region of New York is one of the best producers of natural cement in this country. Hydraulic limestone is found more or less in many states specially those of the Appalachian region of the east. Others occur in the west and in the region of the great lakes. Some idea may be gained of the extent of this industry at the present day by stating that the works for making natural hydraulic cements are found in New York, Pennsylvania, Maryland, Virginia, West Virginia, Ohio, Illinois, Kentucky, Minnesota, Kansas, Utah, New Mexico, Wisconsin and Texas. According to the U. S. geological survey there were 71 plants in operation in 1896, which produced 7,970,450 barrels of natural cement worth $4,049,202. Over 50% of this was made in New York. In fact it was in New York state that the first natural cement in this country was made, and the United States exceeds all other countries of the world in the quantity of natural cement produced. As mentioned in another portion of this report however portland cements are rapidly crowding out the natural hy-

draulic cements. As said before natural cements are made from limestone which contains an admixture of silica, clay and magnesia. The natural hydraulic limestone found in the United States however varies considerably in composition.

The hydraulic limestone can be divided into two classes based on the different amounts of carbonate of magnesia which they contain. In one class it does not exceed 3% or 4%, in another 15 to 35% is found. Most of the hydraulic limestone of the United States is magnesian but that of the Lehigh valley and the upper Potomac valley is not. Likewise some of the deposits of the west, but it can be said in general that over 90% of the rock used is magnesian. The Rosendale and the Louisville cements contain 15 to 25% of magnesia. The amount of the two carbonates in the two limestones varies from 54 to 75%, while silicates and silica may vary from 20 to 47%. The rock may also vary in one locality.[a]

It often happens that the different strata of hydraulic limestone in any one quarry are not all equally well suited for making natural cement, so that before entering into any quarrying method which involves the mixing of all the beds the availability of the different ones should be determined beforehand by experiment. Their adaptability depends on the amount of silica and silicates which they contain and also on the percentage of magnesia and also sometimes on the percentage of sulfur and alkalies. In addition the silica should be combined with the alumina, and the rock should also be dense. The two classes of natural cement mentioned above, namely the magnesian and the nonmagnesian differ distinctly in other properties. The magnesia cements do not heat on mixing and with water they set and strengthen slowly but in the end are as strong as the lime cements. They do not resist frost well when first used, and often careful preparations have a tendency to expand a year or two after use. The lime cements when carefully made have a tendency when made into mortar to heat on the one hand when too rich in lime and on the other hand to bloat when too rich in silicates or overburned. They acquire strength rapidly, having

[a] Richardson gives analyses of different strata in a Maryland quarry, Brickbuilder, 1897, p. 152.

nearly as great a tensile strength at the end of from one to 28 as the magnesian cements. They resist frost better than the latter but at the age of a year very often have not strength enough and are at times inferior, more brittle and crystalline with a tendency to deteriorate in strength. The perfectly prepared and carefully made cements of this class are the best natural cements in the world. The Roundtop cement of the Potomac valley is typical of the highest grade of the lime cements as the numerous Rosendale brands are of the magnesia class.

Manufacture of natural cements. Physical properties of the stone. Of primary importance is the density of the rock. A light rock does not burn well or give a cement of suitable volume, weight or density. The specific gravity at 78° F. should not be below 2.7, and preferably be 2.8. Some stones have a specific gravity of only 2.65, but they are inferior. The best rock is obtained from those portions of the quarry which are beyond the range of weathering. Richardson gives the following density for the Rosendale rock:

Nearest surface	
Light rock	2.83
Dark rock	2.849
Medium	
Light rock	2.815
Dark rock	2.841
Deepest	
Light rock	2.827
Dark rock	2.845

The Fort Scott, Kan., rock which is nearer the surface has a density according to Mr Richardson of only 2.73, the Roundtop rock, Maryland, is 2.731, the hydraulic limestone of Illinois is only 2.667 and does not produce as dense a cement. It is also desirable that the various ingredients of the rock should be as thoroughly mixed in as possible. If the sand is coarse or the clay in lumps or the carbonate in pockets by itself the rock is not adapted for making cement. Generally mere inspection will supply information on this point, and the size of the particles can be

determined by dissolving a weighed fragment in acid and determining the size and quantity of the insoluble particles of sand remaining. The residue of the Rosendale found at various depths are quoted by Richardson as follows:

	Per cent of residue on sieve 200 mesh, 100 mesh, 50 mesh,		
Nearest surface			
Light rock		2.9	
Dark rock		0.0	
Medium			
Light rock		0.0	
Dark rock		0.0	
Deepest			
Light rock	0.6	0.6	0.4
Dark rock	1.2	0.5	0.3

On treatment with acids the rock retains its shape but the clay is dissolved out and the residue can then be broken down with the fingers. If a coarse rock must be used the burning should be slow in order to give a combination between the lime and silica every possible chance to take place.

Chemical composition of natural cements. The amount of carbonate in each hydraulic limestone must not exceed 75% and preferably 70%, and where the quarry contains several strata of different degrees of richness it is possible to bring about the proper composition by mixing the magnesian stone, probably making the best cement known provided they contain enough clay. Yet the Maryland rock with .68 and .44% of carbonate and only 4.58 of magnesia, while the silica and clay amount to 29.66%, are examples of this kind. In any single rock the amount of magnesia should not exceed 40% and should preferably be 25%. A stone with more than this latter amount has a tendency to expand slowly with age specially if it runs low in clay. A western New York rock with 37% of carbonate of magnesia and less than 2% of silica and silicates is an example of this. The Rosendale cements contain only about 20% of magnesian carbonate with 30% of clay. The amount of silica and silicates present is highly important for they influence the hydraulic properties of the

limestone, and as said before the silica should be in combination with the alumina. Can this case be determined partly from the quantity of alumina contained in the stone? For example two stones, one from Akron, N. Y. and the other from the Rosendale region show according to Richardson respectively 35% and 29% of insoluble material, but from the amount of alumina and iron present we can see that there is very little clay in the Akron stone, while there is much of it in the Rosendale stone, the former having only 4.84 of alumina and iron, while the other has 10%. The Rosendale in consequence makes a very superior cement, while the Akron shows the qualities resulting from a deficiency in clay but an excess of magnesia. The effect of this deficiency in clay is to form a cement which heats and sets too quickly, but an excess of clay can also be injurious as already stated. Sulfur when present in the limestone is generally in the form of gypsum, namely sulfate of lime or pyrites or iron sulfid. Both of these substances are seldom present in sufficient amounts to be injurious. They may occasionally become reduced in burning when combined with iron oxid to produce a green color. Alkalies such as potash and soda are harmless unless present in more than 2%; an excess of them makes the rock fusible and such material has to be rejected. The following alkalies percentages in different natural rock cement is given by Richardson.

Alkalies in hydraulic cements

Milwaukee, K_2O	.87
Milwaukee, Na_2O	1.64
Fort Scott, K_2O	.70
Fort Scott, Na_2O	1.33
Akron, Star, K_2O	1.39
Akron, Star, Na_2O	.23
Akron, Obelisk, K_2O	1.60
Akron, Obelisk, Na_2O	.52
Buffalo, K_2O	1.44
Buffalo, Na_2O	.41

The formation of one of these alkalies over the other depends on the species of feldspar from which it is derived.

Burning of natural rock cement.[a] In America the sheet iron kiln is frequently used. In the Rosendale district an elaborate system of mining is conducted to get out the raw material. The raw material occurs generally in two beds of rock known as the dark rock and the light rock. These beds vary in thickness, but generally the former is about 18 feet thick and the latter 12 feet, and there are barren layers about 10 to 15 feet thick separating the two cement deposits. As the formations have been very much disturbed in Ulster co. N. Y. the cement beds are found dipping more or less steeply. Under these conditions with comparatively small beds of productive rock in a mountainous district it soon becomes unprofitable to work the cement in open quarry. The natural development therefore has been a resort to mining by a system of slopes and headings similar in general scheme to anthracite coal mining in Pennsylvania. This work is evidently expensive and would be much more so if it were not that the rock coming from these light and dark strata is practically all of it available for making cement and requires comparatively little sorting or separating after it is mined. As the boundaries of the beds are sharp very little useless rock has to be quarried. Such things also contribute to reduce the cost. Power-drills are generally employed in the Rosendale mines with high explosives to displace the rock. Some of the mines have a great deal of water which requires to be pumped regularly to keep the headings dry. According to Mr Lewis a somewhat similar system of mining is resorted to in Cumberland, Md. In Pennsylvania (the Lehigh district) the work is all done in open quarry on large deposits of suitable rock, requiring little stripping or sorting.

The kilns used on natural cement are all of the lime-kiln type. That is, the shaft is generally cylindrical, drawn into a hopper at the bottom and open at the top. The rock without any preliminary preparation, is charged at the top in alternate layers with coal and the clinker is drawn at the bottom. The operation is continuous and as the temperature of calcination is compara-

[a]Much of the information relating to this subject has been taken from Mineral industry, v. 7.

tively low the output of cement a ton of coal is large, the yield varying from 50 to 120 barrels a ton of fuel. The Campbell grate used by the Milwaukee cement co. is an improvement which has advantages in a more uniform burning of the clinker and in a considerable economy in fuel. This grate differs in design but is similar in idea to a grate which was introduced in the Lafarge cement works in France some years ago.

The burnt rock falling from the bottom of the kilns is generally carefully sorted to exclude the overburnt and the underburnt clinker and there is usually a mixing of material from different beds of rock to produce a product having the qualities desired in the finished cement. The hard burnt clinker being excluded, the calcined rock is soft and easily reduced to powder. The lumps are first broken up in cast iron crushers, and are then ground to powder in millstones. These answer the purpose very satisfactorily and economically for natural cement and are generally preferred to more modern mills. It is a recent practice to pass the material over a separator after it has been cracked so as to take out the material which has been already powdered and thus relieve the work on the mills.

In the natural cement trade there are several standards of weight a barrel, as follows: Rosendale, 300 lb. net; Pennsylvania, 280 lb. net in barrels, 300 lb. net in sacks; western standard, 265 lb. net.

In regard to quality of the cement there are very considerable variations in the new materials and it is rather difficult to adopt any criterion. Cements of the Rosendale district will ordinarily show a tensile strength of 70 lb. at one day neat, and 95% of the raw material will pass the no. 50 sieve. This a very fair standard of quality for natural cements. In the Lehigh valley district of Pennsylvania the manufacturers are making a grade of natural cement which they style "improved" cement, and which is made from a mixture of natural cement with a percentage of the product of portland cement kilns. This cement shows higher tensile strength than the rock cement and commands a rather better price.

In color there is a very great variation among the rock cements, varying all the way from a light cream color to a very dark drab color, which is a characteristic of the cements of the Rosendale district. There is no standard in this regard and the color indicates nothing in regard to the quality of the cement. There is also a considerable variation in the specific gravity of the cements, though generally it is about two sixths. It depends chiefly on the percentage of iron in the material, the greater the amount of iron the higher the specific gravity.

Vast quantities of natural cement are used in the middle western states from the gulf to the lakes and from Ohio to the Rocky mountains. This demand is supplied chiefly from brands made near Milwaukee, Wis. Louisville, Ky. and Utica, Ill. while lesser amounts come from Fort Scott, Kan. and Mankato, Minn. All these are cements but their character and composition vary considerably. Richardson gives a number of tests of these.

Large quantities of cement are made along the Lehigh river near Coplay and other places. This cement is in some respects very similar to that of the Potomac valley, it is quite free from magnesia, sets very quickly and is as a rule what is known as fiery. While it gives great initial strength it is quite inferior to the Potomac cement. The rock from which it is now made has a much more important application for the manufacture of portland cement. Richardson makes the following classifications of natural cement based on the examination of those made in various portions of the United States.[a]

1 Lime cement with only 2% or 3% of magnesia, 13 to 15% of iron and aluminum oxid and 20% of combined silica.

2 Lime cements with as little magnesia but with less silicates than class 1, and consequently less satisfactory and more fiery.

3 Magnesia cements with a maximum of not more than 15% of magnesia, the same amount of iron and aluminum oxid and 15 to 20% of combined silica, and in addition considerable uncombined silicates as they are not thoroughly burned.

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a Brickbuilder, Jan. 1898, p. 14.

4 Magnesia cement with a large amount of magnesia, namely over 20%, less alumina and iron and less undecomposed silicates than in the preceding class.

5 Magnesia cement efficient in alumina and iron oxids as well as in combined silica.

6 Magnesia cements thoroughly burned, made from rock having a smaller amount of silicates than those of class 4, with only a medium per cent of magnesia and little uncombined silicates.

Cements of the first class set and acquire strength rapidly and increase in this direction for a long period but the final result is a more brittle mortar than is obtained with the magnesia brands. This class includes the lime cements of the Potomac valley. According to Richardson the second class has not as variable a relation of silicates to lime, and consequently the cements are apt to be fiery and not as satisfactory. They are shown to improve by the addition of portland cement, after which they can be used quite successfully. This class includes those of the Lehigh valley. The third class is represented by the best Rosendale brands, which set and acquire strength slowly, but which continue to develop it for a long time and eventually are very strong and tough. The fourth class includes cements like those of western New York which have been, while containing an unusual amount of magnesia, burned so hard that little of the silicates remain undecomposed and uncombined with the lime and magnesia, and in consequence are apt to stand a long time after use, unless carefully hydrated. The fifth class is one in which the cement is essentially a lightly burned, highly magnesian material in the preparation of which the heat has not been sufficiently high or prolonged to bring the greater portion of the silica in composition with the lime or magnesia, in this respect being in contrast to the preceding class. The hydraulic principle and strength are therefore largely due to the magnesia and carbonates rather than to the silicates and aluminates. Examples of this are those cements made at La Salle, Ill. The last class fortunately is a cement in which there is rather less mag-

nesia than in the two preceding classes, and less aluminum and iron oxid than in the third class. Though they are burned so thoroughly that there is but a small per cent of silicates uncombined, still as Mr Richardson says, all of these cements will when properly burned and carefully handled give successful results in the large majority of cases. As a rule natural cement mortars will acquire a satisfactory strength with sufficient time, though it may have originally been very weak, or subjected to unfavorable influences due to the conditions under which it was used.

The American natural cements are made from argillaceous limestone of Silurian or Devonian age. In New York, Pennsylvania, Maryland, Virginia, Georgia, Kentucky, Indiana and Wisconsin the natural rock cements all come from the same horizon, most of the limestones used for making natural cements being highly magnesian. The following analyses illustrate the composition of these natural cement rocks from different points in the U. S. In sampling a cement bed for analysis and test the greatest care has to be used.

Lewis considers that the purest and the most homogeneous deposit, and the one presenting the largest acceptable working bed is that of the Lehigh valley. This is now being used to make portland cements. The following analyses give a composition of natural rock cements.

Lewis gives following analyses of rock cements:

Locality	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Authority
Lawrenceville	29.00	10.40		32.35	19.92	A. W. Dow, Wash. D. C.
Norton's Rosendale	24.30	7.22	5.06	33.70	20.94	Booth, Garr't, Blair
Old Newark Rosendale	24.42	8.16	3.96	36.30	16.93	"
Lawrence	22.77	10.43		34.54	21.85	S. B. Newberry
Utica, N. Y.	35.43	9.92		33.67	20.98	Gillmore
Cumberland	28.30	10.12	4.42	49.60	3.76	A. W. Dow
Milwaukee	25.16	6.33	1.71	36.08	18.38	Mfrs. anal.
Lehigh V. Pa	26.50	9.40	2.00	53.50	2.40	Pa. G. S.
Louisville, Ky	21.10	7.51		30.16	7.00	
Cumberland	36.60	14.58	5.12	37.50	2.73	A. W. Dow
"	25.70	12.28	4.22	52.69	1.44	"
Round top	30.02	13.55	3.00	44.58	2.76	"
"	28.36	9.85	3.07	45.04	2.82	"
Potomac	26.65	12.38	2.14	33.20	12.56	"
Vassy (Fr.)	22.60	8.90	5.30	52.69	1.15	E. Candlot
Yonne	23.40	12.90	3.30	47.70	1.05	"
Argenteuil (Fr.)	29.55	8.35	4.10	47.50	3.85	"
Tsckerkasoff (Russ.)	24.29	6.53	5.80	42.10	10.15	"
Sheppey (Eng.)	....	45.60	....	50.30	2.85	Redgrave
Harwich (Eng.)	....	47.00	....	48.00	4.00	"

At the present day natural rock cement is made in 14 states, including 100 plants and 70 firms. Their production is as follows:

District	No. firms	Am. outs. in bbl.	Per cent of total
Rosendale	15	3 500 000	41.9
Louisville, Ky. and Indiana	15	1 750 000	20.9
Pa. dist. Lehigh valley	6	750 000	8.97
Erie co. N. Y.	4	550 000	6.59
Illinois	2	550 000	6.57
Milwaukee dist.	1	475 000	5.68
Maryland and West Virginia	5	275 000	3.28
Schoharie and Onondaga dist.	10	200 000	2.39
Kansas	2	140 000	1.68
Minnesota	2	85 000	1.02
Ohio	3	35 000	.42
Virginia	3	20 000	.24
Georgia	1	15 000	.18
Texas	1	15 000	.18

NATURAL ROCK CEMENT INDUSTRY

The first cement in this country was made from water limerock in 1823, its nature being discovered by accident. It was found while the D. & H. canal was being put through Ulster co. and it was notice that the lime which was burned from certain strata near Rosendale hardened under water instead of slaking. Similar discoveries followed rapidly at other localities, and as a result water limerock was found in western and central New York, in the Lehigh valley of Pennsylvania, in the James, Potomac, and Ohio river valleys, the result being that natural rock cements were made at all these localities at a comparatively early date.

In 1897 the total production of natural rock cement was 7,781,377 barrels. This was unequaled by any other country, the nearest approach to it being France with 6,000,000 to 7,000,000 bbl. a year of both hydraulic limes and hydraulic cements.

The United States is probably in the lead, due to excellence and abundance of raw materials. Greatest production was in 1892. Since then both product and price have decreased. One reason for this is the increase in the portland cement industry.

PORTLAND CEMENT

Portland cement was discovered by Joseph Aspin of Leeds, England, who desired to make an artificial cement that would replace natural hydraulic cements. It received its name because it hardened under water to a mass resembling Portland stone.

The use of hydraulic cement is very old, still the industry has been developed entirely in the present century. In this country the portland cement industry is widespread and active but still not enough to supply the home markets, for the growth of the portland cement industry has been greatest abroad up to the last three or four years.

In England portland cement is made chiefly in the Thames and Medway districts where white and gray chalks and river mud are used. In Germany the portland cement industry is developed chiefly in the northern portion of the empire, the region about Stettin and the Rhine valley being important centers of production. In these localities the materials used are chiefly chalks and marls which are mixed with clay. In southern Germany and Austria as well as Switzerland hard limes are used, in northern France marls, chalks and clays are the materials employed.

The enormous development of the portland cement industry in the United States as well as the amount of material used both native and foreign may be judged from the following table which gives the production of portland cement in the United States from 1891 to 1897 inclusive and also the imports for these years. These imports include shipments from Germany, Belgium, France, England and Denmark.

	1891 bbl.	1893 bbl.	1895 bbl.	1896 bbl.	1898 bbl.
United States...	454 813	590 652	990 324	1 543 023	3 692 284
Imports	2 988 313	2 674 149	2 997 395	2 989 597	2 013 818
Total.......	3 443 126	3 264 801	3 987 719	4 532 620	5 706 102
Exports		14 276	83 682	85 486	36 732

This shows that the total consumption has increased between 30 and 40% and that this increase has been supplied mostly by

American factories, the imports having remained nearly stationary. It will be noticed that in 1883 the United States also began to export some portland cement. With the increasing use of portland cement as well as the increasing number of purposes for which it can be used it is easily understood that an enormous future awaits this industry. In this connection the following remarks of Prof. S. B. Newberry may be quoted:

General remarks on portland cement. The American cements have largely replaced foreign ones throughout the United States. This is specially true of English and Belgium cements, which are generally considered inferior to the best German brands. There is no difficulty whatever at present in selling a good American portland cement in St Louis and Chicago at a higher price than any well known English cement, nevertheless the fact remains that there is among contractors a considerable prejudice in favor of certain brands of German cements, and that the latter still command a higher price than the American. This prejudice is unfounded and is therefore certain to depart in time, but it still exists. American cements can be made at a price which will allow them to be sold cheaper than the best imported German, and where the two come together in competition on large contracts the work is generally made to the American manufacturers on the basis of price. This was clearly shown on the letting of a large government contract at Pittsburg last winter. The offers were as follows:

1 Belgium cement	\$2.50 a bbl.
5 German cements, average price...............	\$2.60 "
4 American cements "	\$2.28 "

The price of portland cement is steadily coming down and the fall is being hastened greatly by the successful competition of American against foreign manufacturers. There can be no doubt that within a very few years practically all the portland cement consumed in this country will be of domestic manufacture. The prices of some however will hardly be the same as they are now. When the demand is completely supplied by American manufacturers we shall have works in this country producing 2000 bbl. a day more than in Germany and the same result will be reached here as in Germany, namely the complete replacement of the common natural cement rock cements by artificial portland.[a]

[a] S. B. Newberry, Brickbuilder, 1897, p. 108.

Portland cement industry in the United States

Portland cement was first manufactured experimentally in this country at Coplay, Lehigh co. Pa. in 1872 at a locality in which natural rock cement had up to that time been made. A second one was at Wampum, Lawrence co. Pa. where fossiliferous limestone and clay were used.

According to Mr Lewis[a] the principal portland cement plants in operation in the United States at the present day together with their dates of establishment are:

Co.	Brand	Locality	Estab.
Coplay cem. co	Saylors, Commercial	Coplay, Pa	1875
J. K. Shinn and bro	Wampum	Wampum, Pa	1876
Millen and sons	Millen	South Bend, Ind	1877
Millen and sons	Millen	Wayland, N. Y	1892
Amer. cem. co	Giant and Egypt	Egypt, Pa	1884
Amer. cem. co	Giant	Jordan, N. Y	1891
Emp. port. cem. co	Empire	Warners, N. Y	1886
Atlas cem co	Atlas	Coplay, Pa	1889
Alpha port. cem co	Alpha	Whitaker, N. J	1891, b'94
West port. cem. co	Western	Yankton, S. D	1890
Buckeye cem. co	Buckeye	Bellefontaine, O	1892
Sandusky cem. co	Medusa	Sandusky, O	1893
Diam. port. cem. co	Diamond	Middle Branch, O	1893, b'97
Bonneville cem. co	Star	Siegfrieds Br, Pa	1894
Vulcanite cem co	Vulcanite	Vulcanite, N. J	1895
Glens Falls cem. co	Iron Clad	Glens Falls, N. Y	1895
Bronson port. cem. co	Bronson	Bronson, Mich	1897
White Cliffs port. cem. co	Setter	White Cliff, Ark	1897

In addition to these there are several smaller ones. According to Mr Lewis the total capacity of the American works is about 3,000,000 barrels, of which 70% comes from the Lehigh valley region of western Pennsylvania and eastern New Jersey.

Composition of portland cements. The essential elements of portland cement are calcium, silica and aluminum. The first is generally supplied by limestones or marl, the two latter by clay. In burning these three elements unite to form a silicate of a complex nature, and it is essential that they be combined in proper proportion in order to give the best results.

In rare instances it is possible to find a natural limestone which contains the three essential elements in the proper propor-

a Mineral industry, 1897, p. 94.
b Rebuilt.

tion. As stated above limestone is sometimes used but in other cases marl is employed, specially in the United States. With marl the expense of crushing and grinding the material is saved, but both have their advantages as well as their disadvantages. The chemistry of portland cement has been most carefully studied by S. B. and W. B. Newberry[a] who come to the following conclusions:

1 The essential constituents of portland cement are tricalcic silicate with varying amounts of dicalcic aluminate. The composition is therefore expressed by the following formula:

$$X\,(3CaOSIO_2) + Y\,(2CaO\,Al_2O_3)$$

From this the proportion calculated, i. e.

Lime by weight $= 2.8\ SiO_2 \quad 1.1\ Al_2O_3$

2 Fe_2O_3 combines with lime at a high heat and acts like the alumina in promoting the combination of the silica and calcium. For practical purposes the presence of ferric oxid in clay is not to be considered.

3 Alkalies, judging from the behavior of soda, are of no value in promoting the combination of calcium and silica and probably play no part in the formation of cement.

4 Magnesia possesses strong hydraulic properties when ignited alone but has none when heated with silica, alumina and clay, and probably plays no part in the formation of cement. It will not replace lime in mixtures the composition of which should be calculated on the basis of lime only without regard to the magnesia present.

Using the formula previously given they made up and tested cements as shown below.[b]

	R. Ca to Si A	CaO	SiO_2	Al_2O_3	Pat. test	Hot test	Tens. str. ¼sq. in. section 7 da.	28 da.
Silicate 95.8, Aluminate 4.2	2.67	72.79	25.21	2.00	Set hard, sound, on glass	Sound, off glass, hard	154	173
Silicate 91.6, Aluminate .4	2.57	71.90	24.10	4.00	Set hard, sound, on glass	Sound, off glass, hard	148	227
Silicate 85.3, Aluminate 14.7	2.39	70.55	22.45	7.00	Set hard, sound, off glass	Sound, on glass,	180	205
Silicate 74.8, Aluminate 25.2	2.15	68.31	19.69	12.00	Set quick, sound, off glass	Sound, on glass	105	84

a Cement and engineering news, 1898. 4:5.

b Cement and eng. news, 1897, 3, no. 6, p. 85.

The actual composition of some leading cements on the market is given below.

Calcium silicates

Formula	R.Ca to Si A	Ca O	SiO_2	Pat. test	Hot test
2 Ca SiO	1.85	65.11	34.89	Set hard, hard 7 da. hard 6 wk.	Sound, on glass hard
2½ CaO_1 SiO_2	2.33	70.00	30.00	Set soft, fairly hard 7 da, hard 6 wk.	"
3 CaO SiO_2	2.80	73.68	26.32	Set soft, fairly hard 7 da. hard 6 wk.	"
3½ CaO SiO_2	3.27	76.56	23.44	Cracked soft, 1 da. hard 6 wk.	"

In good portland cement Dr Michaelis considers that the ratio of the total silicates to the lime should be about as 1 to 2 and that the variation from this ratio should only be within narrow limits. Cements rich in lime set more slowly, but harden better than those poor in lime. Cements rich in silica generally set slower that those rich in alumina but the former harden very energetically in the beginning and are better for use under salt water.

According to Dr Michaelis (Schoch, Mörtel-materialien, p. 85) the celebrated German portland cement manufactured at Stettin in Germany has a silica percentage of nearly 25% with 5.7 of alumina and 2.5 of ferric oxid.

A material like the chalk of Theil is for instance admirably suited for the manufacture of portland cement to be used in marine work, its composition is:

silica 24
alumina 2.80
ferric oxid .90
lime 70

Schoch expresses the opposite opinion from Newberry and considers that alkalies act as a flux, and they can be replaced by calcined soda. He also states that they are of great benefit in connection with the hardening process of cement, as they convert the silica into a soluble condition so that it combines with the lime when wet.

An addition of ⅓% to ¾% of fluorspar is very beneficial for bringing about an easy clinkering of the materials. Nearly all cements contain some magnesia and sulfur, which come originally either from the clay or from the fuel used. Redgraves's *Calcareous cements* states that all mixtures containing 77% of carbonate of lime will when sufficiently calcined give portland cement of fair

quality. Compounds with too much clay fuse too easily and the resulting cement is light in weight, sets quickly, has a brownish color and never becomes thoroughly hard (ibid p. 39). Moreover it crumbles when exposed to the weather. Overlimed cements, that is where the part made of lime in the slurry ranges above 77% or 78%, give a cement which will stand the hottest fire without fusing.

Such cements when burned are slow setting and hard to grind, and portland cement made from such mixtures is liable to flow and swell.

In Europe the clay is generally mixed with marl or chalk, but in this country comparatively little marl is used. In this country Prof. S. Newberry[a] gives 20 works as mixing limestone with the clay, and seven using marl, and of these latter four are in New York state.

Marl is cheaper to use for the manufacture of portland cement as it is softer and finer grained and consequently needs little grinding. It always has a large percentage of moisture which must be expelled.

Redgrave gives the following analyses of English portland cement mixtures:

1 Mixture made at Folkestone from gray chalk and gault clay.

2 Forest of Dean limestone and clay.

3 Mixture from Barrow lias quarries.

All dried at 100° C. but 2 and 3 have perhaps also lost some H_2O.

	1	2	3
Sand	2.50	5.57	2.58
Silica	11.83	9.61	11.41
Ferric oxid	1.97	2.42	2.34
Alumina	5.23	3.45	4.80
Iron pyrites	tr.	......	.43
Calcium carbonate	74.18	75.89	74.09
Magnesium carbonate	1.29	1.50	2.61
Calcium sulfate	.18	.16	.21
Potash	.90	.88	.93
Soda	.31	.39	.46
Water	1.82	.61	.43

[a]Mineral resources of U. S. 20th rep't U. S. geol. surv. pt 6.

A clay or Medway mud from Gillingham is as follows:

Silica	38.413	Sand
Alumina and ferric oxid	1.856	
Silica	25.249	Hyd. silicates
Alumina	14.244	
Ferric oxid	6.744	
Lime	.810	
Magnesia	1.727	
Potash	2.957	
Soda	.773	
Water	3.384	
Pyrite	.214	

Clay used for the manufacture of portland cement should not contain an excess of sand nor iron. Clays low in iron are usually of a gray or blue color and light yellow on weathering. The clay should be fairly siliceous, and the more amorphous silica present the better. Michaelis (Hydraulische Mörtel u. Portland-Cemente, p. 99) gives the following typical examples:

	1	2	3	4	5	6
Silica	60.06	59.25	60.00	62.48	68.45	64.72
Alumina	17.79	23.12	22.22	20.00	11.64	24.27
Ferric oxid	7.08	8.53	8.99	7.33	14.80	7.64
Lime	9.92	....	4.18	6.30	.75	1.89
Magnesia	1.89	2.80	1.60	1.16	.....	.....
Potash	2.50	1.87	1.49	1.74	1.90	.....
Soda	.73	1.60	.72	.37	2.10	.....
Calcium sulfate	.60	2.73	.89	.60	.....	.....

1 Province of Saxony ... 4 Mark Brandenburg
2 Vorpommern ... 5 } Medway
3 Oberharz ... 6 }

Cements high in alumina have a tendency to expand and to blow or to check. Magnesia is also supposed to cause expansion after a lapse of a considerable interval, while sulfates are looked on as causes of disintegration of portland cement when exposed to sea water. Cements low in lime and without an excess of alumina but high in silica are simply of low strength as under burned cements. If the alumina goes above 8% it is considered

high, if below 5% it is considered very low. Mr Richardson considers that over 3% of magnesia is an excessive and undesirable quantity, and the proper limit for sulfuric acid is 1½%. The following are the percentages of magnesia and sulfuric acid in portland cements which have been placed on American markets during the past few years.

MgO	SO_3
.86	1.25
2.79	1.71
1.81	1.24
1.45	1.1
1.68	1.50
2.48	1.36
2.84	1.53
1.16	2.71
2.73	1.51
1.85	1.39
1.32	1.32

Specific gravity of portland cement. This is ascertained by determining the volume of an oil which does not act on cement, such as dry oil of turpentine, displaced by a known weight of cement. For rapid work in the determination of the specific gravity of cement a form of volumenometer has been devised (Min. Ind. 1896, 5 p. 81) which is considered to be free of most of the defects found in those generally used. It consists of a small flask with a short slender graduated neck; the lowest graduation mark on the neck is 14 c. c. and the capacity of the flask is known and equals 64 c. c. The instrument is used by running into it a 50 c. c. oil of turpentine from a pipette which has been accurately calibrated against the flask. As the oil of turpentine is introduced by the pipette the neck of the apparatus is kept dry and the known weight of cement, viz 50 gm can be readily added through a small funnel without blocking the tube. The shortness of the neck conduces to the easy introduction of the cement. The plan of first placing the known weight of cement in the flask and then running in 50 c. c. of oil appears at first

sight preferable to the method described above but the complete displacement of the air entangled in the cement is less easily accomplished than when the cement is showered down through the liquid. The temperature of the oil of turpentine must be known but need not be fixed at any standard point, and after the operation the volumenometer, which is stoppered to prevent evaporation, is brought to the same temperature by immersion in the same vessel of water as that used for the stock bottle of turpentine. All hydraulic cements have specific gravity such that the displacement of 50 gm falls between 14 and 20 c. c. This renders the graduation of the stem ample, but it is obvious that with any material differing largely from the specific gravity of three, more or less than 50 gm can be taken so as to bring the displacement within its range.

Good well burned cement as it comes from the mill has a specific gravity of less than 3.15. It is generally higher than this and may even reach 3.20. The specific gravity falls rapidly when the cement is aerated.

Structure and color

Even when ground to the finest degree portland cement shows sharp grains. To a great extent the color of the product is produced by a combination of the shades of the individual grains. Naturally portland cement should be white but this becomes covered up by the colors of the iron and manganese compounds formed during the burning.

Furthermore when fluor spar is used as a flux it develops a dirty grayish brown color in the clinker. Sometimes the color of the cement is changed artificially.

Tests

In addition to the tensile strength test of portland cement the hammer test is sometimes tried. A machine has been devised known as the Böhme hammer machine, which consists of a hinged hammer operated by means of a spur wheel. This spur wheel is turned by means of a crank, and the wheel acting on

the hammer causes it to be lifted and dropped in rapid succession. The hammer weighs two kilograms. According to the speed with which the wheel is turned the hammer can be made to deliver a greater or less number of blows within a given period (Schoch p. 241).

Setting strength. It has been found that the final strength which different cements attain in the process of hardening corresponds with the rapidity with which they first set. For instance a cement which sets very quickly and which may attain great strength in a few hours will not as a rule compare favorably after a month or two with one which sets slowly, while portland cement hardens much more rapidly than natural cements but sets much slower. Of course there will be a variation in this respect depending on the brand of the cement, and those which are considered the most desirable are those that continue to harden after a long period. According to Mr Richardson,[a] American portland cements seem to gain most of their strength in a few days, while the German brands will be inferior in strength at the end of 28 days but will continue to increase for nearly a year afterward and finally attain an equal strength. Even within the narrow limits of composition allowable for good portland cements there is still a chance for variations which will produce marked differences in character. Some of these variations have been noticed. The set of cement is much influenced by the amount of lime specially when the cement is under burned, or by a large amount of alumina. As a rule the more lime a cement contains the harder it is to bring about the proper combination in burning and the higher the temperature and the longer the heat that is required. When properly made cements with a high percentage of lime set more slowly but are stronger and better for ordinary uses.

Composition of American portland cement

The American portland cements are made from a variety of materials which resemble each other chemically rather than geo-

[a] Brickbuilder, July, 1898, p.147.

logically. As the cement is made from artificial mixtures it is frequently possible to use all grades of limestone and clay bearing rocks. Though portland cement is made at many places and from material of widely different character, portland cement materials are not so very numerous and the raw products have to be mixed within narrow limits. The following analyses are given by Lewis in volume 7 of the *Mineral industry*, the European being given for the purposes of comparison. Following them is also given a table showing the composition of both the American and European brands of cements.

Analyses of raw materials

	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	$CaSO_4$	H_2SO_4	Insol.	H_2O & Org
Lehigh Valley, Pa. cement rock	14.68	5.32	1.12	69.26	......	3.67	......	2.29	......	......	1 68 *c*
Lehigh Valley, Pa. cement rock	15.40	4.26	1.38	74.66	......	2.66	......	.86	......	......	1.88 *c*
Lehigh Valley, Pa. limestone ..	5.87	1.59		88.00	......	4.00	......	......	......	......	— *d*
Lehigh Valley, Pa. cem. mixt ..	13.97	5.07	1.88	74.10	......	2.04	......	......	......	......	1.82 *c*
Lawrence co. Pa. limestone	4.14	.21	1.77	90.47	......	1.00	......	......	......	......	2.03 *c*
Warren co. N. J. cem. mixt	14.16	6.64		73.96	......	3.13	......	......	......	......	*d*
Glens Falls, N. Y. limestone ...	3.30	1.30		......	52.15	......	1.58	......	.30	*a*	8.37
Glens Falls, N. Y. clay	55.27	28.15		......	5.84	......	2.25	......	.12	......	......
Warners, N. Y. marl	.26	.10		94.39	......	.38	......	......	......	......	4.64*d*
Warners, N. Y. clay	40.48	20.95		25.80	......	.99	......	......	......	......	8.50*d*
Sandusky, O. marl	......	1.72		92.70	......	.53	......	2.06	......	1.28	1.13*d*
Sandusky, O. clay	64.70	11.90	9.90	......	.9	......	.7	......	......	......	11.90*d*
Bronson, Mich. marl	1.65	......	.81	90.66	......	tr	......	......	.66	......	5.59*d*
Bronson, Mich. clay	62.10	20.09	7.81	......	.65	......	.96	......	.49	......	7.90*d*
Yankton, S. D. chalk	2.15	2.72		93.72	......	......	......	......	......	......	*d*
Yankton, S. D. chalk	8.20	7.07		83.59	......	......	......	......	......	......	*d*
Yankton, S. D. clay	57.98	18.26	4.57	......	1.75	......	1.83	......	1.28	......	12.08*d*
Arkansas chalk	4.42	2.21	1.03	95.29	......	......	......	......	......	......	*e*
Arkansas chalk	6.09	3.52	1.20	87.93	......	......	1.06	......	......	......	*e*
Arkansas clay	53.30	23.29	9.52	......	.36	......	1.49	......	......	......	5.16 *e*
Arkansas clay	65.12	19.05	7.66	......	.34	......	.31	......	......	......	6.12 *e*

a CO_2 46.98 *c* Pa. geol. survey *d* Mfr's anal. *e* Branner, Proc. Am. Inst. M. E.

Analyses of European materials

	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	Ins.	H_2O ign.
English white chalk .. from	.66	......	.35	93.60	......	.21	.....	.....	......*a*
" " " .. to...	1.59	......	.74	97.90	......	.10	.....	.....	......*a*
" gray " .. from	1.67	.93	.38	96.50	.....	.50	.....	.....	......*a*
" " " .. to ..	6.84	1.14	.46	87.35	......	.10	.....	.....	......*a*
" cement slurry.......	11.77	4.45	2.13	69.97	......	2.87	.....	1.24	7.59*a*
" " "	11.83	5.23	1.97	74.18	......	1.29	.....	2.53	1.82*b*
" Medway clay........	63.66	16.10	6.74	.....	.81	......	1.73	.....	3.38*c*
" Tyne clay............	55.83	28.04	7.78	......	......	2.57	.....	.....	......*b*
								SO_3	
German Hamburg chalk.....	1.55	.50		97.50	......	......	.19	.20	......*d*
" " clay	52.50	17.35	5.75	......	4.48	......	3.24	.94	14.00*d*
" Stettin marl	19.70	3.66	1.34	73.92	......	.97	.....	.32	......*d*
" " clay	54.60	18.20	5.40	......	2.80	......	3.16	.99	18.10*d*
" Rhine limestone	3.00	.42	.53	94.50	......	.....	.86	.13	......*d*
" " clay	50.70	19.13	8.37	......	2.68	......	3.20	1.64	13.40*d*
Belgian Beerse "	65.50	18.55	6.01	......	.38	......	1.18	.14	......*e*
" Visé chalk	1.42	.577		96.80	......	.45	.....	.....	......*e*

Following is the table of American cements:

Brand	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Authority
Alpha	22.62	8.76	2.66	61.46	2.92	1.53	Bootle, GB. B.
Atlas	21.96	8.29	2.67	60.56	3.43	1.43	"
Giant	19.92	9.83	2.63	60.32	3.12	1.13	"
Saylors	22.68	6.71	2.35	62.30	3.14	1.88	"
Vulcanite	21.08	7.86	2.48	63.68	2.62	1.25	"
Empire	22.04	6.45	3.41	60.92	3.53	2.73	"
Jordan	21.86	7.17	3.73	61.14	2.34	1.94	"
Diamond	21.80	7.95	4.95	61.90	1.64	0.79	"
Sandusky	23.08	6.16	2.90	62.38	1.21	1.66	"
Bronson	20.95	9.74	3.12	63.17	.75	0.86	Mfr's anal.
White cliffs	22.93	10.33		64.67	.94	1.05	"

Below are given European cements:

Brand	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Authority
White Label Alsen	20.48	7.28	3.88	64.30	1.76	2.46	B. G. B.
Dyckerhoff	20.64	7.15	3.69	63.06	2.33	1.39	"
Germania	22.08	6.84	3.36	63.72	1.32	1.82	"
Hemmoor	21.14	6.95	4.01	63.24	1.44	1.47	"
Lagerdorfer	23.55	7.47	2.40	61.99	1.42	1.07	"
Brook, Shoobridge co	22.20	7.35	4.77	61.46	1.35	1.87	"
Francis	22.18	8.48	5.08	61.44	1.34	1.56	"
Condor	23.87	6.91	2.27	64.49	1.04	.88	"
Candlot, Fr.	22.30	8.50	3.10	62.80	.45	.70	Candlot
Boulogne, Fr.	22.30	7.00	2.50	64.62	1.04	.75	"

In most of the European cements the lime runs from 60 to 65% while in the American ones it seldom exceeds 63%. In the French and Belgium cements the sulfuric acid is low in order that they may comply with the engineer's specifications. The portland cements made in the eastern United States generally show more magnesia than the western ones. The maximum percentage of

a Heath *b* Redgrave *c* Stanger and Blount *d* Candlot *e* Michaelis

this material in American is about 4%, while in the European ones it is 2.5%. Magnesia was formerly considered very objectionable but opinion is now receding on this point. Those American brands containing 4% of magnesia are not shown to be at all detrimental.

In the various numbers of the *Thonindustrie Zeitung* for 1897 and 1898, i. e. vol. 21 and 22, will be found a number of articles and discussions concerning the effect of magnesia in portland cement. Elaborate experiments of R. Dyckerhoff abroad have not shown any injurious effects to come from 4% of magnesia.

Many American manufacturers adulterate cement by adding calcium sulfate. This generally acts as a dilutant and it should always be stated when done. The German association has declared against any addition except up to 2% to regulate setting time.

It is the general practice in the United States now to put in 2% calcium sulfate to produce slow set.

Tables showing the increase in strength which results from an increase in time occupied in setting.

Pounds to a square inch

Results reported by Dyckerhoff prior to 1880.[a]

No.	One sort of cement	Setting time	Neat-cement Briquette					Briq. 1 cement, 3 sand				
			7 d.	28 d.	12 wk	25 wk	1 yr	7 d	28 d.	12 wk	25 wk	1 yr
1	As mfrd.	0° 20′	323	405	518	620	700	115	168	238	302	360
2	Same w. .5% gypsum ..	3° 30′	315	456	572	623	650	142	212	339	353	390
3	" .1% " ..	10° 0′	375	508	568	695	780	159	238	311	368	384
4	" 2% " ..	14° 0′	423	543	688	718	805	180	263	305	375	410
5	No gyp. but kept in store for some mos.	10° 30′	318	450	550	592	618	168	218	318	360	431

Results reported by John Grant in 1880.[b]

Mixture	7 d.	31 d.	60 d.	90 d.
1–1 briq.; average of 5	107	159	188	267
1–1 " w. . H_2SO_4 added to water; average of 5	129	227	260	255

a Pro. Inst. civ. eng. 62:92
b Ibid, p. 89, 90.

Results replaced by Prof. Tetmajer in 1894.[a]

Number of cem.	% of plaster paris added	Strength of sand briq. 1–3 lb. sq. in. 3 d.	7 d.	28 d.
4	.0	....	160	248
	1.0	...	212	298
	2.0	....	167	254
5	.0	174	285	307
	.5	225	305	344
	1.0	227	320	408
	1.5	230	381	399
	2.0	182	290	400
	2.5	184	295	390
	3.0	115	235	369

Results of Candlot in 1891.[b]

Mortar	Time, d.	0% lb.	Sulfate lime 1%	2%	3%	4%
Heat cem. briq	7	485	645	533	435	264
	28	673	738	674	790	483
1 cement to 3 sand briq	7	223	252	263	185	126
	28	333	377	377	367	201

Lewis considers these results remarkable as regards strength and not explained.

Candlot shows in a series of experiments that the slow set is due to the fact that "the sulfate in conjunction with free lime present in the cement prevents hydration and reaction of the aluminate of lime. As it is this salt which determines the set, the cement accordingly becomes slow setting. The necessity of free lime being present is shown by the fact of its slow set disappearing as the lime becomes hydrated by exposure."

No advantage in strength due to the addition of sulfates is gained in long time tests.

Burning portland cement

The furnace practice is quite varied at the present time in America. The style of the kiln first used for portland cement in

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a Mitth. d. Ans. zur Prüfung v. Baumaterialien, 7 Hft. 1894, p. 39.
b Ciment et Chaux Hydrauliques, Paris 1891, p. 254.

this country was the English dome kiln. This kiln represents English practice of 25 years ago, and kilns of this type are more numerous yet in America than any other style. They are intermittent in operation. In preparing the kiln for burning it is customary to pile wood and coke for several feet above the grate, and then above that dried slurry and coke in alternating layers up to the door at the base of the stack. The doors in the side of the kiln are then sealed up, the fire started at the bottom and allowed to burn its way through the clinker to the top. The doors are then opened and the clinkers discharged through them and from the bottom. The kiln is then recharged for another burning. The operation is then repeated, the kiln being recharged about once in a week or 10 days. This kiln is rather expensive in fuel and produces an output averaging only three to six tons of cement a day in a month's run. A good deal of sorting and picking of the clinker is required to exclude the underburnt and vitrified material. Until 1889 these were the only kilns used in this country. At this date however the Atlas cement co. of New York began to experiment at Coplay, Pa. with revolving continuous kilns, employing crude petroleum for fuel. The oil was blown in by jets at one end and the products of combustion passed into a stack at the upper end of an inclined revolving cylinder. This kiln has been patented in England by Mr Frederick Ransome who also secured an American patent for it. Since 1889 it has been successfully developed and used by the Atlas co. and other manufacturers in America. Though this type of kiln has been unsuccessful in England, in this country there are about 40 of them in operation, both on the hard raw material of the Lehigh valley and on the soft, wet marls of Ohio and Michigan. The revolving continuous kiln therefore is to all intents and purposes an American device since its only successful development has been in this country. Originally employed with producer-gas it was subsequently modified so as to use jets of crude petroleum, while latterly experiments have been made with a view to utilizing pulverized coal as fuel, and several plants are working kilns employing this fuel.

The raw materials for cement enter this kiln in dry powdered form by a spout at the upper end and are carried forward and downward by the revolution of the furnace towards the fireplace at the lower end, the burnt clinker finally falling out of an opening at the lower end of the cylinder. Certain improvements in the way of auxiliary cylinders for regenerating the heat in hot clinker have been perfected, and the Atlas cement co. has also worked out a scheme for sprinkling and cooling the clinker in a third cylinder so that when discharged from this it will be ready for immediate grinding in the mill.[a]

At Yanktown, S. D. the Johnson type of kiln is used. This is quite similar to the dome kilns but has long horizontal flues between the kilns and a central chimney. In this flue and on top of it the wet slurry is deposited and is dried by the products of combustion. The kiln is then recharged by taking up the dried slurry from the bottom of the flue and placing it with layers of coke in the kiln.

The Dietzch type of kiln is also used especially in Ohio. This kiln is the most successful of the German kilns at the present time, being specially economical in fuel and producing a much larger output than any form of noncontinuous kiln.

In 1893 the Coplay cement co. built a kiln of the Schoefer or Aalborg type which is quite similar in its conception to the Dietzch kiln, but instead of an offset in the shaft it is narrowed in the center above the stoke-holes so as to produce a high temperature in a narrow zone. This kiln is also economical in fuel but like the Dietzch kiln is rather expensive in manual labor. The Coplay co. built eight more of these in 1893, and the year following the Glens Falls cement works, of Glens Falls, N. Y. built six of them. In 1896 the White cliffs portland cement co. of Arkansas built a plant also with Schoefer kilns. Fig. 6 shows a section of the Aalborg kilns.

In 1897 designs were under consideration for a continuous kiln of the French type, approaching in general scheme and outline

[a]Most of this description of the process of burning is taken from Lewis's article in Mineral industry, p. 7, already referred to.

a new continuous kiln perfected in France in recent years. This kiln is not so economical in fuel as the German or Danish kilns but is extremely economical in manual labor. None of them has as yet been built in this country.

Accordingly there are in present use in portland cement manufacture five different types of kilns requiring three different methods of preparation for the raw materials regardless of differences of preparation which may be required due to the character of these materials.

The kilns, plant, etc. of the leading manufactories are as follows:

Manufactory	Kilns	No.	Approximate output kiln barrels a day
Coplay cement co	Schoefer continuous	9	55
Coplay cement co	Ordinary intermittent	23	30
American cement co. Egypt	Ordinary intermittent	56	30
American cement co. Jordan	Ordinary intermittent	6	30
Atlas cement co	Revolving continuous	20	150
Alpha cement co	Revolving continuous	8	150
Vulcanite co	Revolving continuous	3	150
Sandusky co	Revolving continuous	4	120
Bronson co	Revolving continuous	3	120
Empire co	Ordinary intermittent	18	130
Glens Falls co	Schoefer continuous	8	60
White cliffs, Ark	Schoefer continuous	8	60
Buckeye cement co	Ordinary intermittent	..	30
Buckeye cement co	Dietzsch continuous	..	50
Diamond cement co	*a* Dietzsch continuous	..	....
Yankton, S. D	Johnson intermittent	6	....
Bonneville cement co	Revolving continuous	3	150

A new plant near Egypt, Pa. and another near Sandusky, O. are both installing revolving continuous kilns.

The character of the kilns being understood the preparation of raw materials can now be more readily discussed. This is described by Mr Lewis as follows: "To accurately proportion

a Rebuilding.

the raw materials and to perfect an intimate mixture of them are the prime factors in making good portland cement. Other things being equal the more exactly the proportions are maintained the greater the uniformity of the cement, the more homogeneous the mixture and the finer the state of division of its particles the greater the strength and hydraulic energy of the product." Admitting these points as axiomatic there is yet of course a practical limit in cost of preparing raw materials which can not be exceeded in successful manufacture. It is thus necessary to achieve on a commercial basis as perfect a mixture as may be. In dealing with so many different grades of raw material there is here an opportunity for the exercise of intelligent adaptation of plant to conditions. At the same cost very different results may be obtained from different apparatus. Indeed in this whole matter of handling raw materials technical skill finds an ample field both in accounting for and proportioning mixtures and its adaptation of plant. It may be frankly admitted that in this respect representative American manufacturers are not yet on a par with similar French and German works. In laboratory facilities and in executive staff European works are superior. The chemist occupies there an assured and responsible position which he has not yet been accorded here. In the general excellence of plant per se, however, American works are now quite on a par class for class with those of continental Europe.

The simplest method of preparing raw materials in American practice is that in use for the hard, dry raw materials of the Lehigh valley, which are burned in revolving kilns. It consists in reducing a suitable mixture of rock to a fine powder. This powder is fed continuously into the upper end of the kiln and is carried forward and downward towards the fire by the revolution of the inclined cylinder, emerging as clinker from the lower end. There is no preparation of raw materials anywhere in the world so simple and inexpensive. The revolving kiln first became a commercial success with this class of material in eastern Pennsylvania, and undoubtedly it is with these argillaceous limestones that it can be employed most advantageously.

To prepare the same raw materials for shaft kilns of any type requires three handlings, namely grinding the rock, making the ground rock into bricks or balls, drying the bricks.

In Pennsylvania a portion of natural rock cement is regularly added in the rock mixture to give plasticity and cohesion to the bricks, which would be entirely lacking without it. When clay and hard limestones are the raw materials two different methods have been used. In the first the limestone is calcined and slaked. A mixture is then made of clay with the slaked lime. In the other method the clay is first dried and ground and then mixed dry with pulverized limestone. In both methods the resulting mixtures are then made into bricks and dried for burning.

In preparing the wet marls and clays of New York for burning in shaft kilns the approved practice is to first dry and grind the clay and to then add it in proper proportion to the wet marl. The mixture is then perfected in pug or edge runner mills and the slurry is balled and dried for calcination.

Various methods of balling slurry are employed. Sometimes it is spread on a floor and cut up in blocks. Brick-making machines discharging a continuous stream of slurry which can be cut to size by wires or knives are employed in both New York and Pennsylvania. The German dry brick-press requiring only a small quantity of water in the mixture is in use in one plant. With marl and clay, or chalk and clay, it is unnecessary to make bricks; the material separates into lumps by shrinkage and drying and can then be broken easily to suitable size. This is the practice abroad with kilns of the Johnson type and in drying marls and clays for shaft kilns in New York state.

For the preliminary drying of clay a revolving dryer of some form or other is found most satisfactory, while for drying brick or balled slurry tunnel dryers are better. Narrow brick tunnels are used and the bricks are stacked on shelving fitted to light cars which are run into the tunnels. Drying is effected either by heat from steam coils set in the bottom of the tunnels or by a current of heated air passing through them. This system of balling and drying slurry is taken from German practice and is

expensive under American conditions. Simpler methods following the recent English or French practice of handling the slurry by pumps and drying in flues or on floors of waste heat from the kilns would be a much more economical method of dealing with wet raw materials. The recent French practice with such materials is superior to anything yet suggested for reducing cost of labor in handling and drying raw materials which require to be balled from slurry before calcination.

A very simple method of preparation of wet raw materials for the rotary kiln is now in use in Ohio and Michigan. The raw materials there are wet marls and clays and it has been found practicable to introduce these materials in a humid or semi-humid condition and burn good clinker. At the works at Sandusky the material is introduced in a semi-humid condition while at Bronson the slurry is introduced into the upper part of the kiln by a pump.

With respect to crushing and grinding machinery for hard raw materials and for clinker American practice is excellent. Crushers of the Blake or Gates type are used for the first reduction, and crackers for the coffee-mill type, millstones and improved mills for the fine grinding. The Griffin mill is an American invention which has found much favor both here and abroad. Its fine grinding is causing it to be favored for raw materials also to the neglect of millstones. In the Alpha works of New Jersey, the Glens Falls works in New York and in a new plant of the American cement co. at Egypt the Griffin mills are used on raw materials to the advantage of the product. The German ball-mill, in which grinding is effected by the impact and abrasion of steel balls rolling freely in a revolving cylinder, has also found favor in recent plants. The material enters by a hollow shaft and passes out as it is sufficiently reduced to go through screens surrounding the cylinders. The ball-mill has been employed on clinker for first reduction only in conjunction with Danish tube mills to do the finer grinding. In it the grinding is done by the impact of flint balls and with a moderate feed very fine grinding can be

done. Because of the simplicity of the means employed these mills have evident advantages.

A rather singular omission in American grinding plants is the absence of separators. In gradual reduction of materials the use of separators to remove the fine stuff before the material passes to the mills is advantageous, because it relieves the mills of that much material and increases their output. Wind separators are very generally used abroad, but are not common here.

The fineness of the best American cements is unsurpassed in any practice and as a general average is superior to foreign-made cements. The following table gives some comparative figures in this respect:

	% passing sieves		
	no. 50	no. 100	no. 200
Saylors	100	96.4	....
Giant	99	94.9	....
Atlas	99.5	92.7	....
Alpha	99.7	94.8	....
Vulcanite	99.6	95.3	....
Sandusky	99.6	92.8	....
Brooks, Shoobridge & Co	98.8	88.3	....
Aslen	99.7	92.4	68.4
Dyckerhoff	.....	....	....
Aalborg	100	99.6	72
Germania	.....	....	....
Condor	99.6	88.5	....

Criteria of quality

The only standards in testing cements which command any general recognition in America are the recommendations of a committee of the American society of civil engineers. The reports of these committees are found in no. 276 and 315 of the society's transactions. The work of this committee has established practice on the following points: 1) the form and section of test briquettes; 2) a standard quality of sand; 3) standard sieves for sand; 4) standard sieves for determining fineness of cements; 5) the rate of speed in applying stress in testing (400

lb. a minute); 6) normal pat tests for constancy of volume; 7) the proportioning of test mortars (cement, water and sand) by weight.

By fixing standards in these important respects the committee has rendered a very great service to this field of investigation. The only tool suggested by this committee for manipulating mortars was the trowel. At first very great differences in results were obtained by different operators manipulating mortars in this way. In recent years however, as good laboratories and skilled operators have become more numerous, there has been a great improvement in this respect and fairly comparable results are obtained. It is an open question whether a change to the foreign practice of employing mechanical hammers would now afford any improvement. A new committee of the society is at present considering methods with a view to revising the old report and extending its scope.

In specifications, test requirements are usually fixed as follows:

For natural cements: fineness, normal pat tests, tensile strength one day neat, tensile strength seven days neat, tensile strength seven days, one to two standard sand.

For portland cements: fineness, setting-time, normal pat tests, tensile strength at seven days, one to three standard sand.

A weight to a unit of volume is not used, the specific gravity determination being substituted for it to great advantage. There is a very frequent use of the boiling test in some form or other. Many of the specifications for this test are very badly considered and illogical. As Dr Michaelis originated this test it may not be amiss to state what the boiling test is as Michaelis makes it, to wit: A thin pan of neat cement three inches in diameter, one half inch thick at the center and drawn to a thin edge at the circumference, is prepared on a piece of moist filter paper set on a glass plate. After setting the cake is removed from the filter paper and placed under cover in a damp atmosphere to protect it from surface drying for 24 hours, at the end of which time the cake is put in a covered bath of cold water. This bath is then heated to the boiling point and is maintained boiling for three hours. The pat is then taken out and its condition recorded.

The standing of an accelerated test of this character is not yet satisfactorily established nor has it yet been adopted in standard specifications abroad. A test of pats in vapor and after setting in water at 115° F. which was suggested by the late Mr Faiji is excellent and entirely free from objection.

With respect to tensile tests of cement the requirements of specifications have been thrown into much confusion by the difference in strength at short periods between cements treated with sulfate of lime and untreated cements. The facts in this regard are fully set forth above in dealing with sulfate of lime. The value of additions of sulfate resides entirely in regulating setting time to make cements more suitable for the uses to which they are to be put. The increase in strength incident to the treatment is without ultimate advantage. Since quick setting cements free from sulfate of lime are important for certain uses, it appears necessary to distinguish between the two in specifications. This is done abroad both in the German and Swiss standard specifications (*see* German and Swiss Normen). For tide-water work, for work in wet bottoms, for concrete deposited in water, for grout, for work in freezing weather and for rapid construction of concrete masonry, quick setting cements are indicated by good practice. When used for such purposes, a distinction in test requirements is desirable. European standards for strength are as follows: German Normen slow setting cement, 227 lb. one to three at 28 days; German Normen quick setting cement, less than above; the setting time is to be considered with the strength. Swiss Normen slow setting cement, 227 lb. one to three at 28 days; Swiss Normen quick setting cement, 199 lb. one to three at 28 days; French quick setting cement, 285 lb. neat at seven days; French quick setting cement, 285 lb. neat at seven days; French quick setting cement, 114 lb. one to three at seven days; French quick setting cement, 498 lb. neat at 28 days; French quick setting cement, 213 lb. one to three at 28 days.

In America there are no standard test requirements for strength of cements and nothing approaching a standard specification. The whole matter is in an extremely unsatisfactory con-

dition both as regards the manufacture and purchasing of cement, and some definite agreement on these points is very desirable.

Uses of cement

Hydraulic cements are employed in America to some extent for all the purposes for which these products have been used in Europe but the relative development for different uses has been distinctly different here from that abroad. For sidewalk pavements portland cement concrete has probably been employed in America to a greater relative extent than anywhere else in the world and with very satisfactory results. On the other hand the use of concrete for monolithic construction in masonry, arch bridges, tunnels and sewers has been much less exploited here than abroad. The best work in massive concrete construction is probably that which has been done in New York harbor, where large monoliths have been made by the New York department of docks. These blocks are not made in situ but are prepared in large timber forms and allowed several weeks' or months' hardening in the air before being placed in dock and bulkhead walls. Blocks of this kind made by the New York department of docks weigh as much as 65 to 70 tons and have proved a very satisfactory type of construction.

The work which has been done on the Wallabout channel in Brooklyn is also a notable and successful use of monolithic concrete masonry for this purpose. In this work the concrete was deposited in situ but as the water was excluded by coffer dams the concrete had some months' hardening in the air before being subjected to the action of the salt water.

Some few bridges have been built in concrete arches, the most considerable work in this line having been done in what is known as a Melan arch construction, in which steel beams are bedded in massive concrete.

A use of hydraulic cement which promises a great development and probably a unique development here is in floor arches in fire-proof construction. A great deal of work of this kind has been done in the larger cities within the last few years, and some

very interesting comparative tests between this method of construction and the hollow tile arches have been made in New York city under the auspices of the New York bureau of building inspection. In these tests the result obtained from concrete ashes has been extremely satisfactory. It is a fact that cement clinker is produced at a considerably higher temperature than the ordinary fire-clay tile. This is specially true when the cement clinker is compared with the hard tile which is semi-vitrified in manufacture. The temperature at which cement clinker is produced in kilns undoubtedly varies with different compositions, but with a percentage of lime of 62 or more in the cement it can be taken for granted that the temperature of calcination is between 2800° and 3000° F. When the cement is made into mortar it of course takes up water which it will lose again at a red heat and in thus losing the water of hydration it will also lose considerable strength. The results of the fire tests however show very clearly that while there is a loss of strength in this way the cement does not disintegrate or lose body. On the contrary the effect produced is to render the concrete which is in immediate contact with the fire light and porous and this constitutes a non-conductor to the body of the concrete beyond it. In a variety of different constructions the concrete has very successfully stood fire test in this way, and indeed results have been so satisfactory and construction of this kind can be effected at such moderate cost that there seems to be no doubt that there will be a great development of the use of hydraulic cement for this type of construction.

DESCRIPTION OF THE LIMESTONE OCCURRENCES BY COUNTIES

The general distribution of the limestones can be seen from any good geological map of the state. In the following pages those counties are mentioned in which the limestone formations become of importance. It is of course not possible to give a detailed description or analysis of every quarry but still it is hoped that enough is given to enable those seeking certain kinds of limestone to find them more quickly.

Albany county

The only limestone formations in this county are the Helderberg and the Corniferous. The former are specially conspicuous as they form the Helderberg escarpment which in this county reaches its greatest elevation.

Onondaga limestone. In Albany county this formation appears as a terrace extending along the foot of the slopes formed by the Hamilton shales. In the northeastern face of Helderberg mountain the outcrop is narrow but it widens to the westward being a mile and a half at Thompson's lake, and after narrowing it again becomes three miles wide in the long slopes northwest of Berne. The formation in this county is a light bluish gray, tough, massive limestone, quite pure but containing lenses of chert. The chert is chiefly abundant in the lower beds of the formation. At times it disappears altogether but this is not usual. One of the best ledges of Onondaga limestone is in the cliffs near Oniskethau creek at Clarksville.

Helderberg limestone. This reaches a large development in Albany county and is divisible into several well marked members. The foremost of these is the Becraft, also known as the Scutella limestone. This rock is of light color, often crystalline and full of fossils. Its average thickness in Albany co. is about 15 feet, and its composition may be inferred from an analysis given of the same bed occurring at Rondout, Ulster co. and Hudson, Columbia co. One exposure of it is in the creek bed south of Callanans Corners. Underlying the Becraft limestone is a series of different beds of very impure, highly fossiliferous, shaly limestone gray and grayish brown in color and probably too impure for any use except building or road making. Their thickness averages 100 feet. Underlying these however comes the Pentamerus limestone which is an important member of the Helderberg formation. Its escarpment is marked by lines of prominent cliffs. It is usually cracked, and its color is that of a red, bluish gray limestone which is of a lighter color on the weather surface. The beds are often cut by vertical joints and there may be occasional layers of shale. The Pentamerus limestone in Albany

county has an average thickness of 65 feet. It is a well known formation and has been quarried for lime at numerous points throughout the state. One of the best exposures of this stone is at the Indian Ladder. Underlying the Pentamerus bed is a series of thin bedded dark blue limestones, which generally crop out at the base of the Helderberg escarpment but are frequently hidden by the talus at the base of the cliff. These Tentaculite limestones are often of a shaly nature. Their thickness along the eastern face of Helderberg mountain according to Darton is about 30 feet. They are also exposed at the Indian Ladder and at South Bethlehem. An excellent section of both Pentamerus and the Tentaculite bed is seen in Callanan's quarry southwest of South Bethlehem, analyses of which are given below. Underlying the Tentaculite are the waterlime beds, also exposed at Indian Ladder and in the floor of the quarry at South Bethlehem, and at both localities they are about four feet thick and represent impure magnesian limestones.[a]

The following analyses made for this report will indicate the character of limestones of the Helderberg series in Callanan's quarry at South Bethlehem:

Lower third of quarry

Silica	9.05
Ferric oxid	.99
Alumina	6.66
Lime carbonate	79.86
Magnesia carbonate	4.17
	100.73

Middle third

Silica	5.12
Alumina	1.45
Ferric oxid	.74
Lime	48.34
Magnesia	2.93
Carbon dioxid	41.22
	99.80

[a]Darton's geology of Albany county, N. Y. state geol. rep't 1893.

Upper third

Silica	11.16
Ferric oxid	1.15
Alumina	3.35
Lime carbonate	79.06
Magnesia carbonate	6.65
	101.37

A sample of Howecave limestone was analyzed by C. A. Chaeffer, but its location in the quarry or even the particular quarry are not given so that it has little value.

Lime carbonate	97.24
Ferric oxid and alumina	.73

Columbia county

Becraft limestone. The limestones in the eastern part of the county are of little importance on account of their impure nature, but on Becraft mountain east of Hudson the stone has been extensively quarried for a number of years to supply the furnaces at Troy with flux. The quarries are all owned by F. W. Jones. The limestone is a coarsely crystalline, fossiliferous rock, of moderately pure and quite uniform character. The stone has to be hauled 600 to 1000 feet to the railroad siding, thus permitting easy shipment.

The following analyses, no. 1 by T. Egleston and no. 2 by the chemist of the Burden iron works at Troy illustrate the character of the stone:

	1	2
Lime	51.40	......
Lime carbonate	......	91.70
Carbon dioxid	41.191	......
Magnesium carbonate	......	3.51
Magnesia	2.233	
Alumina	.635	1.01
Ferric oxid	1.819	.55
Silica	1.842	1.89
Sulfur dioxid	.145	.049
Phosphorous	.149	.022
Water	.271	
	99.685	98.731

Clinton county

The Trenton and Chazy limestones occupy a broad belt which extends along the western side of Lake Champlain from Peru northward to the Canadian boundary, the western edge passing close to West Chazy, Chazy and Coopersville.

Chazy limestone. This limestone is well exposed at the village of Chazy as well as in other portions of Chazy township, specially just north of Plattsburg, and on Bluffpoint two miles south of the latter place, whence it extends south into Peru where the lower portion of the formation is well shown. The aggregate thickness of the Chazy limestone at Chazy village is 740 feet, while at Valcour it is said to be 890 feet. The rock is quarried at a number of points either for obtaining marble, rough building stone or stone for lime.

Black river limestone. The rocks of this group occur as massive dark colored beds, but are well exposed at numerous points in Chazy overlying the Chazy limestone, but outside of the village and in Chazy township it is not very well exposed. According to Cushing it has a thickness of 30 to 50 feet and is a brittle black limestone with a conchoidal fracture.

Trenton limestone. This is also well exposed in Chazy township and in addition in Plattsburg township. Cushing states that in the bed of the river just east of the Chazy village 150 feet are exposed lying on the Black river limestone, while on Crab island about 200 feet of it can be seen. The lower portion of the Trenton limestone generally exhibits beds of a slaty character and is probably of insufficient purity for any chemical use except that of making common lime and for fertilizing purposes. Also in northeastern Plattsburg township, and extending into southeastern Beekmantown, the rocks according to Cushing form a series of black slaty limestones which are excellently exposed on Cumberland head.[a]

[a] Cushing. Geology of Clinton county. An. rep't N. Y. state geol. p. 513.

The Chazy limestone is of high purity and makes a most excellent quality of lime.

The following is an analysis made by D. H. Newland:

Silica	.72
Alumina and ferric oxid	.39
Lime carbonate	96.24
Magnesium carbonate	3.02
	100.37

The quarries are near the railroad and the product can be easily shipped.

Dutchess county

The limestones in the eastern part of the county are a continuation of those found in Westchester co. and follow the line of the Harlem River R. R. while those found in the central and western portions of the county are a continuation of the Orange co. Cambrian limestone belts. The former are metamorphosed limestones and partake of the nature of marble, being highly crystalline, while the latter are not.

The eastern belt. While there are outcrops of the limestone at a number of points in the valley followed by the Harlem railroad, only two large openings have been made. These are at Dover Plains and South Dover.

At Dover Plains G. and J. H. Ketcham have operated a quarry along the highroad one half mile southeast of the town. The rock is a soft, fine grained dolomite of gray or white color. The opening is about 200 feet long, 20 to 30 feet wide and 10 feet deep. No analysis was made of the stone but several samples were examined to determine their insoluble matter, which ran from 2% to 3%.

The South Dover marble co. has a large quarry on the hill two and one half miles northeast of the station. The rock is a fine grained white dolomite and has hitherto been used only for structural purposes. It has to be hauled to the railway.

The rock in appearance is very free from impurities. The following analysis of the rock was furnished by the superintendent of the company:

Silica	.70
Ferric oxid	.25
Alumina	.37
Lime	30.63
Magnesia	20.25
Soda	.12
Potash	.46

The limestones in the western part of the county are usually a hard, fine grained bluish gray rock, containing less magnesia than the whiter phases to the southeast and east.

It has been used for lime but on the whole is too siliceous so that the resulting lime would be lean.

Large quarries have been opened in this belt of Calciferous as its siliceous nature makes it a splendid material for roads. An analysis of this stone from Clinton point two miles above New Hamburg gave:

Lime	29.07
Magnesia	16.29
Carbonic acid	40.76
Alumina	2.33
Ferric oxid	.47
Silica	10.17
	99.09

Erie county

The only limestone formations represented in this county are the hydraulic or water limestones, the Onondaga and the Corniferous. According to Bishop:[a]

The northern edge of the Corniferous limestone together with the Onondaga limestone and the upper part of the hydraulic limestone form a well marked escarpment, which runs in a general southwest direction from the Genesee

[a]Geology of Erie county, 15th an. rep't N. Y. state geol. p. 305.

county line to Buffalo. Most of this distance the escarpment is nearly parallel to the Bloomingdale and Williamsville road. The hydraulic limestone is generally visible at the base of the escarpment where it forms a layer of variable thickness in the face of the cliff. Sometimes it forms a terrace from a few feet to 200 yards in width which runs parallel to the escarpment. This is specially well marked between the Williamsville and Buffalo city line. The Onondaga limestone in Erie county forms a thin band between the hydraulic limestone and the overlying Corniferous limestone. It varies in color from blue gray to a light gray, and also varies in thickness, reaching its maximum of 35 feet in Fogelsonger's quarry at Williamsville. It is the same thickness two miles further on but then begins to thin outrapidly. The formation in Erie county instead of being of one continuous bed is really a series of lenticular masses occurring at the same horizon. The Corniferous limestone in Erie county forms somewhat of an escarpment as already mentioned. The rock outcrops are not as a rule very extensive but good ones occur a few miles below Mill grove near a dam across Endicott creek, and again in the bed of the same stream for three miles below Wilhelm, and also near the same place. Again this limestone is found in Gage creek at Kieffer's quarry near the transit road about a mile west of Lancaster.

Hydraulic limestone. This extends through Williamsville, Clarence and Akron. Along the whole line of its outcrop it has been quarried at numerous places but generally only for building purposes. The section at the works of the Buffalo cement co. gives the following relations of the three limestones:

Flint and limestone, Corniferous, 3 to 9 ft

Onondaga lime 5 ft 8 in.

Loose friable limestone 6 in.

Gypsum crystal 6 in.

Hydraulic limestone, porous, known as bull head, 7 ft

Cement rock used for burning, 3 ft 8 in.

Impure hydraulic lime at bottom

The bull head stratum furnishes the great part of the water lime used for building purposes.

Onondaga limestone. One or two of the lenticular masses already mentioned occur near Williamsville in the quarry of Fogelsonger & Young. It is highly fossiliferous and quite pure as shown by

the following analysis made by H. Carlson and quoted by Bishop:[a]

Lime carbonate	96.54
Magnesia carbonate	1.00
Iron and alumina oxid	.84
Silica	.17
Sulfur	.101
Phosphorus	.017
	98.668

Some of the rock is used for smelting purposes and the waste is burned for lime.

Corniferous limestone. The chief use for this is also for building operations. The largest quarry in Erie co. is that of the Buffalo cement works but there are numerous other smaller ones. The limestone while making a good building material on account of its hardness is very cherty in places, and therefore for any chemical or similar work would probably have to be handpicked. The limestone is usually thick bedded.

Essex county

Three distinct areas of Chazy and Trenton limestones occur in this county. The first forms Willsboro point and extends southward as far as Whallonsburg. A second area begins at Westport and extends southward about six miles. A third area forms Crown point and extends southward to the town of that name. A fourth is on Larrabee's point.

The Black river limestone member of the Trenton is usually heavy bedded, very tough and compact. The rock has been quarried on Crown point.

On Crown point the Trenton proper is 150 feet thick, but is usually thin bedded, showing alternations of limestone and shale layers.

The Trenton has been used at several places for making lime but no definite statement can be made concerning the purity of

[a] Geology of Erie county, 15th an. rep't N. Y. state geol.

any given beds as they are variable. At times the rock is quite low in silica.

Quarries have been opened on Willsboro point and in the town of Essex.

A partial analysis of the Chazy limestone on Willsboro point furnished the writer by Prof. J. F. Kemp showed:

Lime	51.00
Magnesia	1.00
Silica	2.43

Greene county

West of Catskill the Becraft limestone has been extensively quarried by George Holdredge.

The rock shows the usual coarse grained fossiliferous character and the beds lie nearly horizontal with a slight dip to the west.

The stone is quite homogeneous and a sample analyzed by the writer and representing the average of the quarry gave:

Silica	2.75
Alumina	1.50
Ferric oxid	1.60
Lime	53.10
Carbonic acid	42.10
	101.05

The quarries lie about one mile from the river and the West Shore R. R.

Herkimer county

Calciferous sandrock occurs in the county around Little-falls and is well exposed in several quarries in the town. It is generally a light bluish gray, fine grained, massive bedded sandy limestone whose weathered surfaces are generally dirty buff.

The following analysis will illustrate well its siliceous and magnesian character:

Silica	10.50
Alumina	3.03
Ferric oxid	.77
Lime carbonate	47.96
Magnesium carbonate	36.89
	99.15

The *Helderberg limestones* extend across the southern edge of the county as a belt several miles wide whose northern limit passes through the towns of Jordanville, Columbia, Cedarville and Cedar Lake. They have been quarried at several places, Columbia among them, for lime burning, but their distance from the railroad is a serious objection.

The Tentaculite limestone is utilized at Columbia south of Littlefalls for the manufacture of lime and has the following composition:

Silica	4.01
Ferric oxid	53
Alumina	.48
Lime	51.82
Magnesia	1.16
Carbon dioxid	41.90
	100.80

Trenton limestone. This group of limestones is of some importance in Herkimer co., but only the Birdseye and Trenton members are present.

Around Littlefalls the Trenton is not over four feet thick according to Darton, but at Ingham Mills the rock is well exposed in the lime quarry, where nearly 15 feet of good stone can be seen. The quarry is on the property of Sherman Butler. The better stone is bluish, fine grained and massive, but in the upper part of the quarry it passes into the Utica slate.

The following analyses represent its composition, no. 1 being the lower massive rock and no. 2, the average of the quarry face:

	1	2
Silica	6.70	8.45
Alumina	3.03	2.72
Ferric oxid	.21	.84
Lime carbonate	89.15	84.60
Magnesium carbonate	tr	3.42
	99.09	100.03

From Ingham Mills the Trenton limestone passes northwestward past Salisbury and Norway to the edge of the county where it forms a belt whose width extends from Poland to Grant. A spur also extends from Poland southeast to Middleville, and it has been quarried at Newport.

Lewis county

The *Trenton* limestone extends across the county in a northwesterly direction and follows the line of the Rome, Watertown & Ogdensburg R. R. It has been quarried at several localities among them Leyden, Lowville and Collinsville.

The limestone is well exposed along the road from Port Leyden to Leyden, one and one half miles south of the former locality on the land of Peter Snyder. The rock here is a fine grained, brittle light gray stone, full of calcite eyes. An analysis of it made by D. H. Newland gave:

Silica	6.50
Alumina	1.67
Ferric oxid	.76
Lime carbonate	88.44
Magnesium carbonate	2.68
	100.05

This same stone outcrops for some distance along the railroad track south of this point.

South of Leyden and below the railroad level is a large quarry of black, finely crystalline limestone on the land of Mrs Christy. The stone has thus far only been used for building purposes. It probably represents a lower bed than the stone in Snyder's quarry. It is of greater purity however as shown by the following analysis:

Silica	1.44
Alumina / Ferric oxid	0.83
Lime carbonate	97.36
Magnesia	1.04
	100.67

The Trenton limestone has been quarried for lime burning at Collinsville three miles north of Port Leyden. The rock here as exposed in Roberts lime quarry is a coarse grained, gray stone, in thin layers 2 to 8 inches thick and often containing irregular partings of bituminous shale. They predominate at times so as to give the rock a shaly character and such portions are discarded. The stone makes a white lime as might be expected from its low silica and iron percentage.

The composition of the stone as analyzed by Mr Newland is as follows:

Silica	3.09
Alumina	1.15
Ferric oxid	.49
Lime carbonate	94.11
Magnesium carbonate	1.63
	100.47

At Lowville the Trenton limestone is exposed in J. Water's quarry, one and one half miles north of the town and along the Rome, Watertown & Ogdensburg R. R.

The upper layers are a black limestone with calcite spots, while the lower ones are a light gray, finely crystalline stone, and it is these latter ones which are chiefly used.

The composition of Mr Water's limestone is:

Silica	3.96
Alumina / Ferric oxid	1.70
Lime carbonate	91.27
Magnesium carbonate	3.78
	100.71

Monroe county

The *Niagara* limestone extends across the county as a belt several miles wide, its northern edge passing through the towns of Penfield, Brighton, Ogden, Gates and Sweden. The upper magnesian member generally forms the outcrops and the weathered surface of the rock has a peculiar granular and spongy appearance.

The upper member, or Guelph limestone, is a grayish brown, finely crystalline limestone containing numerous small cavities. The rock is very low in silica and has a large amount of magnesia, making it well adapted for refractory linings in furnaces.

The lower beds of Niagara limestone are hard, compact and generally highly siliceous in Monroe county.

The Niagara shale underlies the Niagara limestone and the transitional beds between the two sometimes furnish a natural cement rock. Beds of this nature outcrop at Shelby falls in the town of Barre.

The Guelph limestone is well exposed in the quarry of the Rochester lime co. at Brighton two miles east of Rochester. The rock is used for lime and gives a lumpy product of yellowish color. The following analysis sets forth well its magnesian character and its comparative freedom from silica:

Silica	1.12
Alumina	27
Ferric oxid	.39
Lime	29.38
Magnesia	22.10
Carbon dioxid	47.39
	100.65

If this rock showed this same character at other points it would show it to be an important bed, and to determine this additional analyses were made by Mr Newland. The first of these represents the average of several samples taken from Snow's quarry at Gates near Rochester:

Silica	.70
Magnesia	20.05
Lime	30.50
Alumina	.95
Ferric oxid	.80
Carbon dioxid	45.24
Ignition	.073
Undet	2.687
	101.000

The last analysis is of a sample from the Copeland quarry in Rochester, collected by G. van Ingen:

Silica	.29
Alumina	.43
Ferric oxid	.46
Loss on ignition	.07
Lime carbonate	56.01
Magnesia carbonate	43.30
	100.56

This shows the rock to be an almost pure dolomite.

The Clinton limestone also occurs in Monroe co. and is to be seen outcropping at the middle falls at the gorge at the Genesee river at Rochester.

No analyses of it are available but it is not a very important formation.

Montgomery county

The Helderberg limestone belt does not come within the limits of the county but both the Trenton and Calciferous are present.

Good exposures of the Calciferous occur near the N. Y. C. & H. R. R. R. at Amsterdam and St Johnsville, Canajoharie and Tribeshill.

According to Darton the Trenton limestone reaches its maximum thickness at Fort Plain where it is 9 feet, but decreases to 7 feet at St Johnsville.

The limestone varies somewhat sometimes being massive as at Tribeshill and at others shaly. In the Tribeshill quarries 12 to 15 feet of massive stone are exposed. Other exposures are seen in the quarries north of Amsterdam.

At D. C. Hewitt's quarry one mile north of Amsterdam the Trenton rock has been used for lime. In the upper quarry the stone is coarse grained and the layers in upper portion of the quarry are quite impure and shaly.

The rock in this upper quarry burns to a brown lime. In the lower quarry which is just below Hewitt's limekiln the stone is much purer and more massive than that of the upper quarry. The lower layers are harder, are light gray and are said to make a whiter lime. Under this comes a bed of lime rock which is practically non-slaking and seems to have hydraulic properties. The lime made at this quarry is fairly white. The composition of the lower limestone runs:

Silica	6.13
Alumina	.79
Ferric oxid	.61
Lime carbonate	88.49
Magnesium carbonate	2.45
	98.57

The upper beds showed 8.92% of insoluble matter.

There is evidently considerable variation in the upper layer as a comparison of the foregoing analysis with the first of the following three shows. They were made by J. M. Sherrerd and published in *19th annual report, U. S. geol. survey*, pt 6.

	Upper layer	Intermed	Lower
Silica	1.25	3.82	5.68
Ferric oxid, Alumina	3.00	1.08	2.76
Lime	52.78	52.46	52.12
Magnesia	None	None	None
Undet (CO_2?)	42.97	42.64	39.44

Another limestone quarry has been opened by George Ross on the eastern edge of the town. The rock has thus far been used only for structural work. It contains some sandy streaks which could be separated if the stone were to be burned into lime. The average composition of the stone is:

Silica	7.46
Alumina	2.48
Ferric oxid	1.07
Lime carbonate	71.76
Magnesium carbonate	18.19
	101.46

This rock is probably Calciferous and not Trenton judging from its magnesian character. Portions of it in the eastern end of the quarry run as low as 4% in insoluble matter.

Niagara county

The limestone passes through the towns of Royalton, Lockport, Cambria and Lewiston. In this county the Guelph or magnesian member is missing but the lower member is of increased thickness. The lower beds overlying the shale are apt to be somewhat siliceous but the upper ones are a crinoidal limestone of greater purity.

The following section of beds composing the Niagara limestone at Lockport is given by Prof. Hall.[a]

5 Thinly laminated blackish gray limestone with thin laminae of bituminous shaly matter, the whole exhibiting a tendency to a concretionary or contorted structure and the surface of the layers marked by small knobs.

4 Grayish brown bituminous limestone, the lower part with irregular cavities containing spar.

3 A dark colored limestone with cavities and veins of spar often concretionary.

2 Irregularly thick bedded limestone of a light gray color, also containing cavities lined with spar.

[a]Geol. 4th dist. p. 89.

1 Encrinal limestone containing numerous crinoid stems. Light gray in color but often spotted with red.

Samples for analysis were taken by the writer from a quarry by a limekiln one and one half miles east of Lockport and along the canal. The rock in this excavation is a light gray, fine grained, massive limestone containing numerous fossils, which are often collected into large bunches. The upper layers of the quarry are thinner and more argillaceous than the lower ones.

The composition of the Niagara limestone in this quarry is shown by the following analysis made by Mr D. H. Newland:

Silica	7.09
Alumina	2.57
Ferric oxid	.96
Lime carbonate	56.19
Magnesia carbonate	33.42
	100.46

South of the town of Niagara Falls the Niagara limestone is quarried for burning lime. The quarry is owned and operated by William Messing. The following is an analysis of this stone made by the writer:

Lime	42.21
Magnesia	17.45
Alumina	1.30
Ferric oxid	.75
Silica	1.70
Carbon dioxid	37.50
	100.91

Oneida county

The Helderberg limestones extend across the southern portion of the county and are crossed by both the Utica, Binghamton and Utica branch of the D. L. & W. R. R.

In the Eastern part of the county the Trenton limestone extends from Poland to Boonville in a belt several miles wide and following the line of the R. W. & O. R. R. The Trenton has

been quarried at Prospect along West Canada creek. Prof. Smock states[a] that a sample tested contained 94.82% lime carbonate.

An analysis from this same quarry made by J. D. Irving gave:

Silica	2.59
Alumina	1.21
Ferric oxid	.61
Lime	52.00
Magnesia	1.04
Carbon dioxid	42.00
	99.51

For some years the limestone quarries in Oneida county were extensively operated to supply flux for blast furnaces, and Prof. A. H. Chester of Rutgers college, New Brunswick, N. J. has kindly furnished the writer with the following analyses:

Localities	CaO	MgO	Fe_2O_3 and Al_2O_3	CO_2	SiO_2	P_2O_5	S	Total
			(2)					
1 Quarries near Clinton, Oneida co. N. Y.	48.68	1.84	1.64	40.29	7.23	....	0.21	99.89
2 Quarry " " (dark)	52.53	0.69	0.36	42.03	1.92	....	......	97.53
3 " " " (light)	35.25	8.94	....	37.52	......	....	.....	....
4 " " " (dark)	43.22	6.08	....	40.65	......	....	.....	....
5 Another " "	48.82	1.48	....	39.99	......	....	.....	....
6 " " "	50.25	1.00	1.50	40.49	5.53	....	0.30	99.07
7 Oriskany Falls, Oneida co. N. Y	50.47	0.83	1.55	40.57	5.56	....	0.21	99.19
8 Same "	52.69	0.84	1.55	42.33	2.57	....	0.14	100.12
9 " "	50.25	1.11	2.14	40.70	5.66	....	0.18	100.04
10 " "	50.80	1.01	1.35	41.02	5.46	....	0.12	99.76
11 " "	50.93	0.85	1.38	40.87	5.82	....	0.07	99.92
12 Quarry near Clinton	53.52	0.46	0.95	42.54	2.48	....	0.04	99.99

Onondaga county

Some of the largest limestone quarries in New York state are situated in Onondaga county. The limestones quarried are the Niagara, Helderberg and Onondaga.

The purest limestone in the county is furnished by the Stromatopora beds and known as the "diamond blue" rock. Much stone of good grade is however also furnished by the Lower Helderberg rock, notably west of Syracuse.

[a] N. Y. state museum, bull. 10, p. 246.

The Niagara limestone is exposed at several places from the northwest corner of the county to Bridgeport. It generally forms a low ridge. At Diedrich's quarry in Lysander village where it has been operated for a number of years, the magnesian Niagara limestone is 5 feet thick and of dark gray color. Near Baldwinsville it is 4 feet thick but rather shaly, in Cicero it is 3 feet thick and was formerly used for making lime. As a rule the Niagara limestone can be easily quarried.[a]

Helderberg. The hydraulic limestones of Onondaga county are mostly dark blue, fine grained rocks in beds 1 to 5 feet thick. They weather to a bluish gray. Most of them are fairly pure but at times contain some magnesia or clayey material. The pure beds belong to the important lime furnishing horizon of the county.

The two beds of hydraulic limestone lie near the top of the group and according to Luther are often separated by 4 feet of impure limestone. In the eastern part of the county the upper layer is 4 feet thick but it pinches out in the Split rock quarry west of Syracuse to reappear again near Marcellus Falls where it is 2 feet 10 inches in Watkins quarry and reaches 4 feet in Corrigan's quarry as Skaneateles. As at this latter place it is only separated from the lower bed by a shaly layer the two practically form one bed 9 feet 6 inches thick.

At Manlius the beds are separated by 4 feet of blue limestone and at Street's quarry near Onondaga hill by 1 foot 8 inches, at Marcellus falls by 1 foot 7 inches, and at Skaneateles they are together.

Luther gives the following thicknesses for the lower waterlime layer in Onondaga county:

Manlius, J. Beahan's quarry	4 ft
Jamesville, E. B. Alvord	4 ft 5 in.
Brighton, Button and Clarke	5 ft
Skaneateles, Corrigan's quarry	5 ft

At Split rock the upper member occurs in the southeastern part of the quarry but is wanting in the western portion, its place being occupied by a 9 foot bed of blue limestone.

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[a] Luther. Geol. Onondaga county, 15th an. rep't N. Y. state geol.

Luther described the hydraulic limestone in Onondaga co. as being brittle, compact, fine and even grained. It is dark colored with a conchoidal fracture but weathers to a light color. The beds are generally well defined but do not as a rule contain any fossils. The rock was discovered in 1818 in connection with work on the Erie canal. As in other cases attempts were made to burn the stone for lime but it was found that it would not slake. The cement rock quarries are generally near the summits of the Helderberg escarpment.

The kilns used in Onondaga are oval with a diameter of 10 feet at the top, 12 in the middle and 3½ at the bottom. They are 28 to 42 feet deep and are generally built of limestone with a lining of fire brick. In starting the kiln a cord of 4 foot wood is put in the bottom, over this 4 inches of anthracite coal, then 1 foot of limestone, more coal and alternating layers of stone and coal to the top. It takes 10 tons of coal and 15 cords of stone to fill a kiln, and this gives 1500 bushels of lime. After the kiln has been burning two or three days the first draw of 250 to 300 bushels can be made at the bottom of the kiln. The product is of course ground before used. For a list of the producers in Onondaga co. *see* Luther's report, p. 270.

Upper Helderberg limestone. This stone in Onondaga co. is a light gray semi-crystalline limestone, the layers being separated by thin seams of shale. The rock is at times variable in its character and may at times become argillaceous. Cherty layers are sometimes common in the upper part of the formation. In the face of the cliff forming the Helderberg escarpment the Corniferous limestone is rarely over a few feet thick, though at the western end of the great chasm of Green lake two miles north of Jamesville the upper 25 feet of the vertical wall is Onondaga limestone.

The chief value of the Corniferous is as a building stone though many portions of it are adapted to the manufacture of lime. Many quarries have been opened in it and the largest now in operation is on the Indian reservation in the Onondaga valley. Analyses have been made of several limestones in this county.

No. 1 shows the composition of lime made from the stone in E. B. Alvord & Co.'s quarry at Jamesville, the analysis being made by F. E. Englehart.

Lime	91.93
Magnesia	3.06
Insoluble	1.88
Sulfuric anhydrid	.73
Ferric oxid and alumina	2.03
	99.63

Another analysis of an average sample gave:

Silica	1.60
Alumina and ferric oxid	.70
Lime carbonate	97.00
Magnesian carbonate	1.11
	101.78

This same quarry also contains several layers of cement rock, of which the following are analyses:

	Upper layer	Lower layer
Silica	10.97	10.95
Alumina	4.46	5.32
Ferric oxid	1.54	1.30
Lime	27.51	30.92
Magnesia	16.90	13.64
Carbon dioxid	37.94	38.31
	99.32	100.00

The composition of the blue limestone in the Split rock quarry of the Solvay co. is as follows:

Silica	5.35
Alumina	.56
Ferric oxid	.61
Carbonate of lime	85.41
Magnesian carbonate	18.86
	100.79

In Rockland and Orange counties there begins another series of belts of the Calciferous limestone formation which extend in a northeasterly direction. These same belts continue across the river into Dutchess co. and also extend up into Columbia co.

In this latter one however they are so unimportant as not to be worth considering.

The Cambrian limestones are found at several places in Orange co. One area occurs around Central Valley and Turners extending thence westward to Monroe. It is finely crystalline, light bluish gray, but rather siliceous. It is however used for lime. Another area extends from a point about two miles south of Sugar Loaf past Stone Bridge, Warwick and New Milford into New Jersey. Its character in this area is similar to that around Monroe and Turners. It may at times become quite siliceous, showing as much as 18% silica, and there may also be a variation between the different layers in the same quarry, one perhaps containing only 2%, while the others may have 15% or 18%.

An area of white limestone extends from Florida through Pine Island and Amity into New Jersey. This is highly crystalline, metamorphosed Cambrian limestone which also underlies a broad belt which extends southwest from Florida through Big Island and Gardinerville to New Jersey. It possesses the same character as the other belt. Another small area is found along the railroad between Neelytown and Campbell Hall. This has been used to a small extent for lime. The Cambrian limestones also outcrop both southwest, west and north of the city of Newburgh.

Rockland county

The character of these Calciferous rocks of the Orange and Rockland county belt may be judged from the following analyses made of samples collected from different parts of the quarry, the analyses in each case representing the average of the quarry.

The first one of the magnesian limestone from Tompkins Cove is as follows:

Oxid of lime	26.34
Magnesia	16.74
Carbonic acid	39.10
Alumina	4.13
Ferric oxid	1.05
Silica	12.00
	99.36

Large quarries have been opened, and the crystalline limestone at this locality close to the railroad station has been used exclusively for road making, it being at present one of the largest producers of this material. Its highly siliceous quality makes it excellently adapted for this purpose.

This analysis shows that the stone is both magnesian and highly siliceous. The following analysis of the Calciferous limestone from Miller bros. quarry on the southwestern edge of Newburgh indicates the rather constant character of the stone. It runs:

Lime	27.75
Magnesia	17.65
Carbonic acid	40.99
Alumnia	1.93
Ferric oxid	1.80
Silica	10.46
	100.58

Newburgh. The Calciferous is exposed in Miller's quarry on the southwestern edge of the town. It is harder than the Tompkin's cove lime and like the latter is both siliceous and magnesian. It has been used to a small extent for making lime.

The following analysis was made by J. D. Irving:

Silica	10.46
Alumina	1.95
Ferric oxid	1.80
Lime	27.75
Magnesia	17.65
Carbonic	40.46
	100.07

Putnam county

Two quarries have been opened, the one near Towner's, the other near Paterson, but the descriptions of them given below will indicate that neither run low in silica.

The quarry at Towner's is one mile northwest of the N. E. R. R. The stone is gray and white, coarsely crystalline and contains

many crystals of white or light green pyroxene scattered through it. Mica flakes are also abundant in the rock. It is a magnesian limestone with considerable silica in its composition.

The quarry at Paterson is on the Haight property half a mile southeast of the railway depot. The opening is about 15 by 40 feet and 60 feet deep. A number of blocks of stone have been taken out but all show the rock to be full of mineral impurities so that it would not make a very high grade lime.

Rensselaer county

A belt of impure limestone of Cambrian age extends from Lebanon Springs to Petersburg, but outcrops are scarce.

Another small area extends from the vicinity of North Petersburg to Eagle Bridge and underlying an area several miles wide west of Hoosick Falls. At this latter locality a number of small quarries have been opened on a hill west of the town and show well the varying character of the stone as well as its purity in certain beds. The rock varies from a nearly pure limestone to a black calcareous slate. It has been used to some extent for flux in a local furnace while some has been shipped to Troy, and at times it has also been used for lime manufacture.

The best stone is found in Cornelius McCaffery's quarry. The section there is nearly 60 feet thick, rather flinty in the upper part but in the lower yielding stone which analyzed:

Silica	1.20
Ferric oxid	1.50
Alumina	2.00
Lime	34.11
Magnesia	8.97

Saratoga county

Sandyhill. Both the Calciferous and Trenton limestones occur in Sandyhill. The Calciferous is quarried by Higley, Monty &

Co. but owing to its siliceous nature it has been used only for structural purposes. The following analysis illustrates the character of the stone:

Lime	29.05
Magnesia	12.80
Ferric oxid	1.02
Alumina	.46
Carbonic acid	38.60
Insoluble residue	18.04
	99.97

The Trenton limestone is exposed about one and one half miles east of the canal and the section is very similar to that found at Glens Falls, the upper layers being somewhat impure and the lower layers showing 8 feet of black limestone evidently of considerable purity.

St Lawrence county

The Trenton-Chazy limestones extend along the St Lawrence river from Chippewa Bay to the northeastern edge of the county. Its southeastern boundary passes through Flackville, Norwood, North Stockholm, Brasher Falls and Fort Covington Center.

At Ogdensburg the stone has been quarried for lime manufacture about a mile west of the town. The stone is thin bedded and only the upper layers of the quarry are used for lime.

The following analyses show not only the dolomitic character of the rock but also the greater freedom from silica of the upper layers.

Upper stone, Howard's quarry, Ogdensburg:

Silica	4.42
Alumina	2.23
Ferric oxid	.16
Lime carbonate	55.87
Magnesia carbonate	37.74
	100.42

Lower stone, Howard's quarry, Ogdensburg:

Silica	17.28
Alumina	5.21
Ferric oxid	.92
Lime carbonate	58.17
Magnesia carbonate	18.46
	100.04

The crystalline limestones of St Lawrence county form a belt many square miles in extent stretching in a northeast and southwest direction, and in addition there are small scattered patches, which are irregularly distributed throughout the county. According to Smyth the largest limestone belt is that which is traversed longitudinally by the R. W. & O. R. R. and extending from Antwerp to a point two miles east of De Kalb Junction. While it is thus seen that the limestone undelies a considerable area, at the same time owing to a scarcity of outcrops its presence is not always noticeable. The linear extent of this belt from Antwerp to its probable end in Canton is 35 miles. Its width in a northwest and southeast direction is variable. It is two miles at Antwerp, six to eight at Gouverneur, but then narrows again. The limestone is highly crystalline in character, and varies in color from a white to a dark bluish gray. It is unfortunately often rendered impure more or less by scattered grains or somewhat similar masses of minerals of which the most important are serpentine and tremolite. In some localities these crystalline limestones reach a high degree of purity. The following two analyses were kindly furnished me by Prof. Priestley of St Lawrence university. No. 1 is a stone used for lime from a locality on the road to Colton and six miles from Canton. No. 2 is from Stevens quarry on Grass river one mile above Canton. The second one is not used for lime.

	1	2
Silica	.50	1.12
Iron oxid and alumina	1.30	1.89
Lime carbonate	88.67	76.48
Magnesia carbonate	9.53	19.97
	100.00	101.11

At Gouverneur extensive quarries have been opened for obtaining marble and much of the refuse is used for lime.

This stone often runs low in impurities, as indicated by the following analysis made by J. D. Irving:

Silica	1.85
Alumina	.23
Ferric oxid	.38
Lime carbonate	92.29
Magnesium carbonate	4.28
	99.03

The crystalline limestone is well exposed at Harrisville, N. Y. in the quarries of the Harrisville marble co. which lie about half a mile from the C. & A. R. R. The rock there approaches very closely in composition to the mine at Gouverneur. At Lewisburg, N. Y. there is a considerable ledge of crystalline limestone on the Hungerford farm, near Lewisburg, about four and one half miles north of Natural Bridge. It is rather far from a railroad, but it has been estimated that it could be put on the car at Natural Bridge for $1.35 a ton. The stone is coarsely granular but not very hard. Certain portions of the rock are very white, evidently quite pure but rather free from silica. At other times it contains an abundance of mica grains.

Ulster county

The limestone formations occurring in Ulster co. together with their thickness is as follows:[a]

Onondaga, 60 ft cherty
Upper shaly limestone, 30–125 ft impure
Becraft limestone, 20–30 ft fairly pure
Lower shaly limestone, 60 ft impure
Pentamerous, 30–60 ft dark massive
Tentaculite limestone, 20–40 ft thin bedded
Cement series, 20–50 ft cement and waterlime
Niagara limestone, 0–45 ft
Wappinger limestone, 200 ft siliceous

[a] Darton. Geology of Ulster co. p. 297.

Of these the Becraft and the cement beds are the most important.

Onondaga limestone. This has been quarried at a number of localities for burning into lime. The stone is generally light blue gray, dense and massive. An unfortunately common feature is the presence of layers of chert though these may be locally absent at times. It predominates chiefly in the upper beds.

Darton states (p. 301) that the outcrop of the Onondaga limestone is practically continuous from the northeastern corner of the county to Wawarsing township.

Around Kingston its area widens greatly, due to the presence of folds, and most of the upper part of the city is built on it. Southward by Hurley and Marbletown the Onondaga formation is prominent in the ridge sloping westward to Esopus creek.

Exposures also abound along the W. S. R. R. northward from Kingston, and, from west of Saugerties to Asbury, along and near the road passing through Cedar Grove and Katsbaan.

Upper shaly limestone. Throughout its whole extent the upper shaly limestone exhibits a large amount of argillaceous and siliceous impurities. The beds are massive but the rocks possess a slaty cleavage and these properties aid in the formation by them of small rough ridges.

It extends across the county parallel with the Onondaga limestone. As far as known it is not available for any of the uses treated of in this report. The upper shaly overlies the

Becraft limestone. This in Ulster co. is the purest limestone of the whole Lower Helderberg series. The beds are massive, bluish gray to reddish limestone, of a semi-crystalline nature and highly fossiliferous.

Scattered through the rock are saucer-shaped masses of white crystallized lime carbonate, from one to two inches in diameter and representing the bases of crinoid heads. The formation according to Darton varies from 20 to 30 feet.

Extensive quarries have been opened in it near Rondout, Eddyville and Whiteport. The lime made from it is of good quality, lumpy but slightly brown in color. The Becraft limestone ex-

tends across the eastern portion of the county from north to south.

It is well exposed between Saugerties and Rondout and about Wilbur and Whiteport, but exposures of it are rare southwest of this latter locality excep at Mill Hook and Highfalls.

Samples for analysis were collected from the quarry of the Newark cement co. at Rondout, and the average of these gave:

Silica	3.87
Ferric oxid	1.34
Alumina	1.07
Lime	54.11
Magnesia	tr
Carbonic dioxid	40.60
	101.29

Another set of samples from the quarry of B. Turner near Wilbur gave:

Silica	7.10
Alumina	2.50
Ferric oxid	1.65
Lime	45.22
Magnesia	tr
Carbon dioxid	39.10
	99.57

Pentamerus limestone. This member of the Lower Helderberg in Orange co. is a hard, dark blue or lead colored, massive limestone. Not infrequently it is somewhat cherty. Its hard and tough character frequently causes it to give rise to cliffs. Good exposures of this rock occur in the cliffs at Rosendale, about Port Jackson, near Eddyville and along the eastern face of the limestone ridge extending from Rondout to Saugerties and West Camp.

They are generally a mile or more from the shore of the Hudson but two miles north of Rondout approach close to it. The Pentamerus limestone has a thickness of 30 to 40 feet.

Tentaculite limestone. This is generally a thin bedded dark blue limestone and forms the base of the Helderberg series. Its thick-

ness varies from 20 to 40 feet and is greatest about Rosendale.

Salina waterlime beds. These underlie the Tentaculite and are of considerable importance as they include the well known cement beds. Darton says, "The usual characters of the formation are thin bedded water limestones, and the cement is of local occurrence."

It is a blue black, very fine grained, massive bedded deposit, consisting of calcareous, magnesian and argillaceous materials in somewhat variable proportions. The beds are extensively developed in the Rondout and Rosendale regions. They come in gradually and are attended by a thickening of the formation from its usual average of 20 to 30 feet to 40 or 50 feet. At Rondout the principal cement bed has a thickness averaging about 20 feet.

It lies directly on the coralline (Niagara) limestone and is overlaid by alternating successions of waterlime and thin impure cement beds. The cement horizon is not exposed far north of East Kingston, but how far it extends to the northward is not known.

It is seen to thicken southward and it attains its maximum thickness in the vicinity of Rondout, thinning out again and giving place to waterlime beds south of Wilbur.

It is seen to have come up again in the Whiteport anticlinal, which brings up a great development of cement beds along its principal axis from Whiteport to Rosendale. They also come out along the eastern limit of the synclinal eastward. "South of Rosendale the cement beds continue up the Coxingkill valley and around the point of the anticlinal by High Falls on the Rondout creek." "Above this place it can be traced but a short distance owing to its deep erosion and heavy drift cover in the Rondout creek valley." It reappears at Port Jackson.

"There are two cement beds in the Whiteport-Rosendale region. The lower one of these averages 21 feet in thickness, and the other averages 12 feet in thickness, with an intervening member of 12 or 15 feet of waterlime beds, but these thicknesses are very variable."

"At High falls the upper bed is 15 feet thick, the lower bed 5 feet thick with 3 feet of intervening beds of waterlime rock. The High falls are over the thicker beds."

Darton also states that "cement may be looked for in the upper Rondout valley, from Port Jackson to Ellenville, but owing to the absence of outcrops this should only be regarded as a suggestion."

Nothing further will be said in this portion of the report concerning the Rosendale cement rock as it is mentioned more fully in the chapter on natural cements.

Coralline or Niagara limestone. This forms a thin bed underlying the cement at Rondout. It is a dark gray limestone of variable thickness. Under the cement at Rondout it is 7 feet, but at the entrance to the Becraft limestone quarries one mile north of East Kingston it is only 5 inches.

Warren county

At Glens Falls the Trenton limestone has been quarried for a number of years for lime manufacture and the product bears an excellent reputation.

There are four companies operating lime quarries but the rock in all of them is very much the same. The section in the quarry beginning at the top consists of:

Thin bedded impure black limestone	12 to 15 ft
Massive black limestone	2 to 3
Fine grained, black, crystalline limestone	15

The upper bed is used for building and also for portland cement, being mixed with the overlying clay; the lower bed makes a high grade of lime. The following partial analysis represents the composition of the upper stone:[a]

Silica	3.90
Alumina	1.30
Ferric oxid	......
Lime	52.15
Magnesium	1.58
Sulfuric acid	.30

[a] Mineral industry. 1897.

The composition of the lower bed is as follows:

Silica	1.10
Alumina	.80
Ferric oxid	.50
Lime	53.17
Magnesia	.75
Carbonic oxid (est.)	42.80
	99.12

The rock has to be carted three quarters to one half a mile for shipment, depending on the quarry from which it is taken. The lime produced is soft but quite pure. It is said to slake rather quickly.

The analysis of the lime in the circular of the Associated lime co. is:

Lime	96.46
Magnesia	.64
Ferric oxid and alumina	1.70
Loss on ignition	1.20

Washington county

The limestone areas of this county though not extensive include some of the purest limestones found in the state. One narrow belt extends from Middle Falls to North Argyle, a second begins at Adamsville and extends northward past the eastern edge of Fort Ann and Whitehall to the Vermont boundary. A third area lies on the boundary between New York and Vermont and along the Rutland branch of the D. & H. R. R. The rock has been extensively quarried at Smiths Basin and west of Fairhaven.

At Smiths Basin the Keenan lime co. has several quarries in the ridge to the east of the railroad. The rock is mostly dark gray to bluish black, fine grained and moderately hard. Its massive character has been somewhat destroyed in places by the shearing and folding to which the rock has been subjected. The upper beds are shaly and siliceous but the lower ones are very

pure. Much of this rock has been shipped to Troy both for use as a flux in blast furnaces and also lime for use in making Bessemer converters.

The following partial analyses will serve well to show the composition of the stone:

Silica	1.38
Ferric oxid and alumina	.58
Lime	55.26
Magnesia	.72
Phosphorus	.004

An analysis of the lime made by Prof. J. H. Appleton gave:

Moisture and carbon dioxid	2.08
Insoluble	1.06
Ferric oxid and alumina	.58
Lime	95.50
Magnesia	tr
	99.22

A third one made by the writer gave:

Silica	.72
Ferric oxid and alumina	1.50
Lime	54.28
Magnesia	.80
Carbon dioxid	43.10
	100.40

The black Trenton limestone is also mined just east of the state line in Washington co. They quarry is situated along the railroad track between Whitehall and Fairhaven and is operated by George D. Harris under the name of the Arana marble co.

The rock is a dark colored moderately hard limestone with very few visible impurities, and in places traversed with enormous streaks of calcite, and at certain portions of the quarry

noticeably at the western end the rock assumes a brownish red color. As a whole it may be said that the stone is very pure and where shale impurities occur they are generally in the shape of horses which can be easily separated in the mining of the rock. The following analysis indicates very well the high degree of purity of this material:

Silica	.70
Alumina	1.00
Ferric oxid	.70
Lime	53.90
Magnesia	1.40
Carbon dioxid	42.50
	100.20

Westchester county

The limestones in this county are all of the same age, probably Trenton-Calciferous. They extend across the county in a northeasterly direction forming several well marked belts which either border or underlie the main valleys. The two most important ones are those along the line of the Harlem R. R. and the Northern R. R. The former has been extensively opened up at Tuckahoe and Pleasantville and so far as examined contains the better grade of stone.

A third important area occurs south of Sing Sing. Other occurrences are northwest of Peekskill, near Somers, Amawalk and Hastings.

The limestones in this county are often highly magnesian, coarse to fine grained metamorphosed rocks. At times they are exceptionally free from silica.

There are two important quarries at Sing Sing, the one belonging to Henry Marks the other to the Sing Sing lime co. The stone in Mr Marks's quarry is finely granular and slightly grayish in tint while the best stone in the Sing Sing lime co.'s quarry is white and coarse grained but possesses a high degree of purity.

A number of samples were collected from Marks's quarry and their average composition is as follows:

Silica	.98
Ferric oxid	.30
Alumina	.84
Lime	31.40
Magnesia	16.96

This it will be noticed represents a high grade of magnesian limestone running very low in silica and probably suitable for the lining of Bessemer converters. There are certain layers in the quarry which have a tendency to become siliceous in their character and these have to be avoided in mining.

The rock from Marks's quarry has been shipped to Newark for a number of years to be used as flux. In this case the sorting was probably not as careful as it would have been for some purposes, and consequently the following series of analyses kindly furnished by Mr G. H. Stone of the New Jersey zinc and iron co. show a greater silica contents:

Silica	6.77	5.94	5.12	2.05
Ferric oxid } Alumina }	1.81	2.82	.75	.99 / 1.11
Lime	45.02	29.05	25.42	34.63
Magnesia	3.16	20.05	22.35	15.37
Phosphoric acid	.027	......	......	......
Carbon dioxid	......	......	......	44.11

The good rock of the Sing Sing lime co. shows even less silica than that from Marks's quarry as will be seen from the following analysis:

Silica	.87
Ferric oxid	.25
Alumina	.57
Lime	31.40
Magnesia	19.95

There are certain layers on the west side of the quarry which should be avoided as they run more siliceous. In structure these layers are thinner than those of the purer stone and more finely crystalline. Their composition was found to be as follows:

Silica	6.75
Ferric oxid	1.08
Alumina	3.02
Lime	28.32
Magnesia	17.94

The best quality of stone makes a very white lump lime.

The quarries at Tuckahoe, Westchester co. are most extensive and are all located in the same stratum, which extends northeast and southwest and has a thickness of about 40 feet.

The firms operating the quarries are O'Connell & Hillery, Norcross Bros. and the Tuckahoe marble co. also known as J. Sinclair & Co.

The rock in all of these quarries is a magnesian limestone of granular character and moderately hard. Its character is quite constant. The beds dip steeply to the west, and those forming the walls of the quarry are very micaceous.

O'Connell & Hillery's is the most southern quarry and is but a short distance from the Tuckahoe railroad station. The rock is used chiefly for making lime. but in recent years the manufacture of marble dust has also been begun.

The following analysis of the stone was furnished by the company:

Carbonate of lime	70.10
Carbonate of magnesia	25.40
Insoluble matter	2.40
	97.90

The Tuckahoe marble co.'s quarry is three quarters of a mile to the north. The quarry is about 400 feet long and 40 feet deep, and up to the present time the stone has been used for building purposes only.

Still farther to the north about one fourth of a mile is Norcross Bros. quarry. The rock is similar in character to the preceding but the quarry is smaller.

Two analyses have been given of the stone. No. 1 was made by Prof. Thomas Egleston and no. 2 by the writer.

	1	2
Insoluble	......	1.33
Lime	30.16	30.68
Magnesia	21.25	20.71
Carbonic acid	47.30	46.66
Ferric oxid	.21	.21
Water	.02	.16
Silica	.24	......
Alumina	.19	......
Loss	.63	......
	100.00	99.75

The quarry at Pleasantville is the largest in Westchester co. It is operated by O'Connell & Hillery, successors to the Cornell lime co. The limestone is very uniform in its character and on account of its white color and coarsely crystalline character has been called "snowflake marble." Nearly the entire production of this quarry is used for the manufacture of marble dust. The composition of the rock according to an analysis given in the 16th annual report of the *United States geological survey*, pt 3, p. 468 is as follows:

Lime carbonate	54.62
Magnesia carbonate	45.04
Iron carbonate	.16
Alumina	.07
Silica	.10
	99.99

This does not quite agree with an analysis made by the writer which represents an average of the quarry as follows:

Lime carbonate	59.84
Magnesia carbonate	36.80
Alumina	.40
Ferric oxid	.25
Silica	2.31
	99.60

A small quarry was once in operation near Scarsdale, Westchester co. but the rock contains considerable mineral impurities.

The crystalline limestone extends up the valley of Anns cove, and Sprout brook for several miles, and is exposed at a number of places, specially along the line of the narrow gage railroad leading up to the Edison magnetic mines. The best exposure of this is in the quarry one and three fourths miles west of Peekskill rock. The rock is a fine grained, grayish white stone, which seems to be the better quality towards the eastern end of the mine where it is of a darker color. The working face exposed is over 75 feet long. The following analysis made by J. D. Irving shows the composition of the stone, and illustrates the point that far less magnesia exists in this limestone than is found in other portions of Westchester co. The rock was formerly quarried for blast furnace flux.

Silica	2.50
Ferric oxid and alumina	1.55
Lime carbonate	81.64
Magnesia carbonate	13.50
	99.19

Other exposures of this same rock outcrop, as low ledges on the property of Mr Higgins about two and one half miles west of Peekskill village. Some of these ledges show a stone of considerable purity while in others the rock is rather micaceous.

The two following analyses kindly furnished the writer by G. A. Stone are from the white crystalline limestone outcropping at the northern end of Manhattan island:

Silica	7.15	10.20
Ferric oxid and alumina	1.06	3.33
Lime	39.57	27.32
Magnesia	10.02	17.99

REPORT

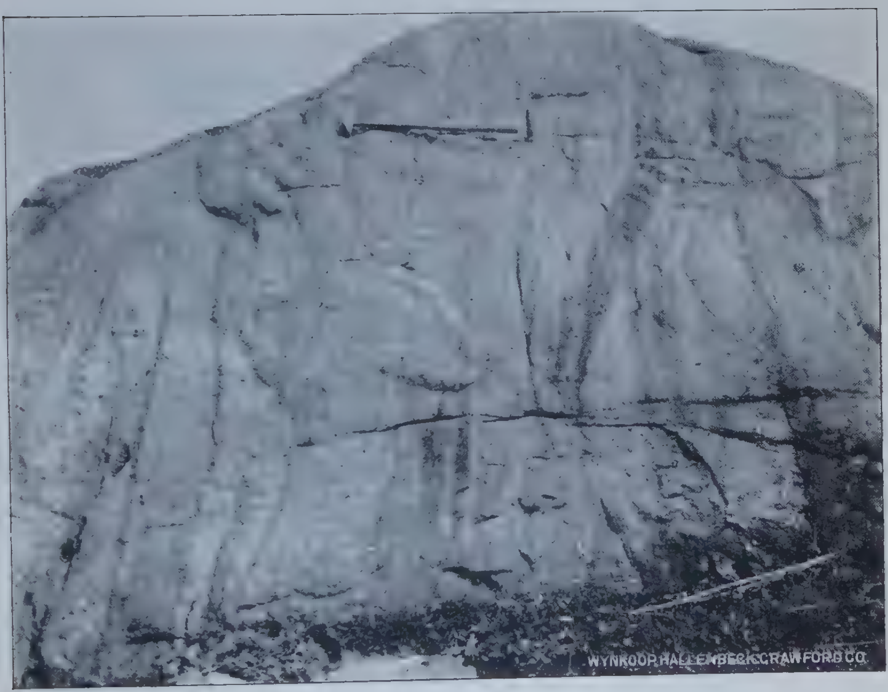
ON

CRYSTALLINE ROCKS OF THE WESTERN ADIRONDACK REGIONS

BY

C. H. SMYTH JR

Plate 1



SYENITE AT HARRISVILLE

INTRODUCTION

As originally planned the field work for 1897 in the western half of the Adirondack region was to consist of two distinct parts. It was thought advisable first to make a somewhat detailed study of what seems, in its bearing upon the great problems of the region, to be a critical area embraced within the towns of Diana and Croghan, Lewis co. and Pitcairn and Fine, St Lawrence co.

After the completion of this work, the intention was to make a reconnoissance into the heart of the region in Herkimer and Hamilton counties. While this trip was planned as a means of acquiring all possible data for use in mapping, its particular aim was to ascertain whether or not the Adirondack region as a whole consists, as has been suggested by Van Hise,[a] of a great central mass or core of gabbro, surrounded by a fringe of gneisses, schists, limestone, etc. with a quaquaversal dip.

The latter half of the plan, thus sketched, was carried through on the lines originally laid down and with satisfactory results. But the Diana-Pitcairn region proved to be so complex that it was found impossible to solve many of the problems afforded in the time available for the purpose and with the very imperfect maps at hand, and the work was finally dropped, to be taken up again it is hoped in a short time. Nevertheless as some valuable data were procured, in spite of the unfinished state of the investigation, the writer will record them in the succeeding pages that they may be available should the completion of the work for any reason fall to others.

DIANA-PITCAIRN AREA

A belt of crystalline limestone crossing this area with a northeasterly trend divides it into two dissimilar portions. The northern margin of the limestone is cut by numerous intrusions,

[a] Correlation papers. Archean and Algonkian, Bull. 86, U. S. geol. surv. 398, 399, 413, 414 and Principles of North American Pre-Cambian geology. 16th an. rep't U. S. geol. surv., p. 771-73.

ranging from granite to gabbro, and these give place farther north to the ordinary gneisses which extend several miles.

On the south the limestone is bounded by a belt of rock whose character and relation to the limestone and gneisses have been the object of special study.

This rock was referred to by Nason[a] several years ago as gabbro, like that of Essex co., and is probably what Van Hise and Williams[b] classed under the same head. A more detailed though brief account of it was given by the writer[c] three years ago. In the latter description the name gabbro was retained, on account of its previous use and from the fact that portions of the rock were found to consist chiefly of plagioclase and pyroxene, but more because the rock was regarded as an outlying portion of the great gabbro masses which at that time were supposed to be very widespread in the Adirondack region.

But in using the term gabbro the writer was careful to state that it was purely provisional and based upon no thorough petrographic study, the discussion in which it was employed dealing with the rock's "geologic relationships rather than its petrographic affinities."[d] It was also pointed out that the rock was quite variable in composition, ranging from gabbro to augite-syenite, and that data were lacking on which to base a conclusion as to the relative abundance of the different varieties. In subsequent casual references to the rock the writer has always accentuated the fact that its petrographic affinities were uncertain, but, unfortunately others have overlooked this qualification and so far as it has been mentioned the rock has been classed as an undoubted gabbro.

So far as the work planned for this region was carried out it indicates that the term gabbro should not be retained for this rock as a whole since the more acid augite-syenite variety forms by far the larger part of the mass.

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a Iron bearing rocks of the Adirondacks, American geologist, 12:28.
b Op. cit.
c Crystalline limestones and associated rocks of the northwestern Adirondack region, Bull. geol. soc. 6:271-82.
d Op. cit. p. 271.

Plate 2

SYENITE, JENNY CREEK

The prominent features of this type of the rock have been presented in the paper referred to and need be only briefly restated here. Feldspar is the predominant constituent, giving to the normal gray variety the appearance of anorthosite. A deep green, non-pleochroic pyroxene, apatite and magnetite, with a varying amount of quartz make up the rest of the rock. In the field (*see* pl. 1, 2, and 3) it varies from almost entirely massive to distinctly gneissoid, the latter variety being by far the most common. Under the microscope the feldspar is shown to be a very fine microperthite, with more or less plagioclase, the former often building a rim around the latter. The feldspars are in large individuals while the other constituents are in small scattered grains or crystals. Some cataclastic structure is nearly always shown and often it is beautifully developed.

The rôle of the quartz is not easily determined as in some cases it is rather abundant while in others it is quite lacking. In average specimens it is to be regarded as an accessory mineral and is not important in classifying the rock.

The mineralogical composition of the rock indicates its affinity with the syenites as stated for this variety in the paper above cited, and this idea is supported by the chemical composition as shown by the following analysis:[a]

SiO_2	65.65	CaO	2.47
Al_2O_3	16.84	K_2O	5.04
FeO	4.01	Na_2O	5.27
MgO	.13	H_2O	.30
		Total	99.71

The figures given for the alkalis suggest the possible presence of anorthoclase, but no separation of the feldspars for more accurate determination has been attempted, as their ever-present intergrowth would make a separation difficult if not impossible. However if the prevailing microperthite is an intergrowth of potash and soda feldspars as is doubtless the case, it would sufficiently explain the alkali content of the rock. And the composi-

a Crystalline limestones and associated rocks of the northwestern Adirondack region. Bull. geol. soc. 6:274.

tion taken in conjunction with the extreme fineness often shown by the microperthite recalls very forcibly the explanation of anorthoclase as an ultramicroscopic intergrowth of potash and soda feldspars.

As the more basic, gabbroitic variety has been found to be the exception and the syenitic variety the prevailing type, in the following pages the term syenite will be used for the rock as a whole, though its wide range in composition is to be kept constantly in view.[a] While no extended petrographic investigation of the rock under discussion has been attempted such data have been sought as might shed light on the question of its origin, though on strictly petrographic data but little reliance has been placed. The structural relations existing between the syenite and the other rocks of the region have been studied as carefully as time would permit, and on them almost entirely have been based all conclusions as to the true nature and history of the syenite.

The study of this particular rock was taken up because it was thought to afford a connecting link between some rocks of certain and others of doubtful origin. As shown in an earlier report some areas of gneiss in the western Adirondack region are without doubt of sedimentary origin and others are as certainly igneous. Small areas of gneiss of composite origin are known, and larger areas are probably igneous, while still others are of wholly problematic origin.

The rock under consideration has been thought to afford a clue which may be of service in making more definite our knowledge of these gneisses and it was for this purpose that its study was begun. But as already stated this study was left very incomplete and from the facts gathered it is impossible to draw conclusions as far-reaching as it had been hoped to reach.

The structural data bearing upon the question of the origin of the syenite were presented in the former paper[b] and in the

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a Since the foregoing was written Prof. Cushing has described similar augite-syenite occurring in Franklin co. in close association with gabbro, of which the syenite is thought to be an acid phase. The two cases are closely parallel but with the quantitative relations of the rock varieties reversed.

b Crystalline limestones and associated rocks of the northwestern Adirondack region. Bull. geol. soc. 6:276.

Plate 3

RIDGE OF SYENITE

present paper only new localities and old ones that have been reexamined need be considered.

The apparent inclusions of pyroxene gneiss of the limestone series in the syenite, occurring about a mile southeast of Harrisville (pl. 4 and 5) were examined again with great care, and the immediate vicinity was gone over thoroughly. The phenomena are even more striking than at the first examination and it seems impossible to explain them as anything but true inclusions in an igneous rock. The pyroxene gneiss is in irregular, angular fragments from a few inches up to several rods in diameter, and is scattered through the syenite (here unusually massive) in the most irregular manner. The pronounced banding of the pyroxene gneiss is variously oriented in the different blocks, and is entirely independent of the prevailing northeast trend of foliation which the gneisses have when in place. But where a gneiss fragment is long and narrow its longest diameter tends to assume parallelism with the prevailing strike. Narrow spaces between adjacent inclusions are filled by the syenite which also sends tongues into the pyroxene gneiss, implying a high degree of plasticity in the syenite while the pyroxene gneiss was entirely sólid. How this could occur except as the syenite was in the molten state it is difficult to see. As if to give added meaning to these phenomena, the syenite close to the inclusions sometimes shows a slight banding parallel to the adjacent side of the inclusion, only to be explained as a low structure.

These facts are restated here because they afford the strongest single piece of evidence as to the origin of the syenite, and would be of the utmost value even were they not supported by numerous other data leading to the same conclusion.

To find in their normal position rocks closely resembling the included pyroxene gneiss it is only necessary to go about half a mile to the northward where rocks of this character are abundantly shown associated with the limestones. From this it is evident that the inclusions show not only that the syenite gneiss is igneous but also that it is younger than and intrusive in the limestone series.

Confirmatory though not conclusive evidence in the same direction is found a few rods north of the locality described where there are several patches of impure limestone ranging from a few feet up to some rods in diameter, which are also with much probability intrusions in the syenite, though as is commonly the case with limestones the contacts are so hidden as to make it impossible to determine the relations with certainty.

Similar phenomena are shown along the low ridge extending westward from near the railroad station in Harrisville. The ridge is formed by the syenite standing up above the more easily eroded limestone of the valley, and the two formations may be seen along the line of contact. This line is, for a supposedly intrusive contact surprisingly straight, suggesting rather at first sight the contact between conformable formations, or perhaps a fault line. But when traced in detail many features appear that can be explained only as the phenomena of an intrusive contact.

A few rods south of the station the syenite appears to send tongues into a fine grained gneiss of the limestone series, but the outcrops are poor and the evidence indecisive.

About one eighth mile west the syenite forms a slightly sinuous contact with the limestone and with a peculiar gneiss, having the appearance of a contact zone. At the same time the syenite changes slightly, becoming nearly white and finer grained. The structure at this point is represented diagrammatically by fig. 1, the section shown being rather less than a rod across.

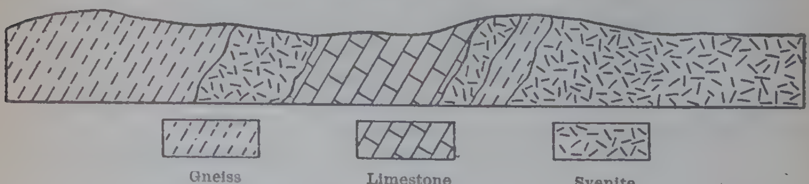


Fig. 1 Contact of syenite with limestone series. Length of section about one rod.

The meaning of the section is however apparent only when the fact is remembered that the structure would be quite different in other sections a short distance away along the strike. The syenite would be found cutting a different horizon of the limestone formation and the details would vary accordingly.

Plate 4

INCLUSIONS IN SYENITE

This fact becomes apparent on going a few rods farther west where the fine grained gneiss like that at the station is present in some quantity. The gneiss is distinctly banded and foliated, and these structures are cut squarely across for a distance of 40 feet by the syenite, which partially surrounds an area of several square yards of gneiss. Still farther west the syenite

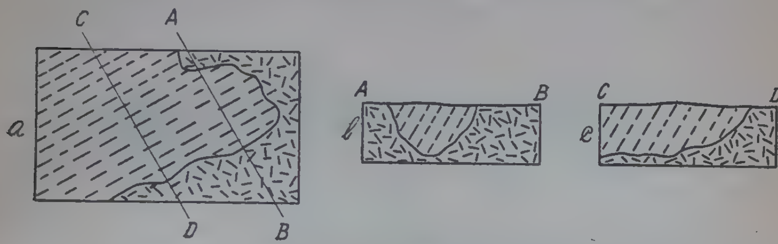


Fig. 2 Contact of syenite with gneiss of limestone series. *a* Plan, *b* section along line *A–B*, *c* section along line *C–D*. Length of sections about 3 rods.

sends numerous lenses into the fine grained gneiss, and contains many included fragments of the latter rock varying widely in size and shape. Some of these inclusions are clearly defined with sharp boundaries but others are somewhat blended with the surrounding syenite as though they had undergone a partial melting. One inclusion is a mass of green amphibole and pyroxene quite unlike the gray gneiss and probably a highly metamorphosed fragment of the limestone.

A diagrammatic section of this locality is shown in fig. 3. The intrusion of the syenite into the gneiss in the form of narrow lenses with their long axes parallel to the foliation is in accordance with a very general rule in this region, to which reference is made in a former report. Lenses and sheets are of frequent occurrence, and the latter in particular often closely simulate interbedded layers.

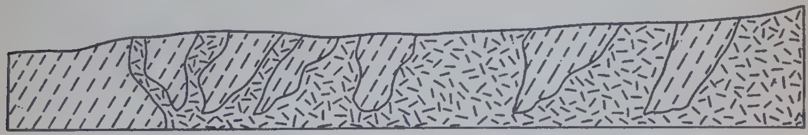


Fig. 3 Contact of syenite and gneiss of limestone series. Tongues of syenite in gneiss and inclusions of gneiss in syenite. Length of section about 12 rods.

About a mile west of the station and just beyond the road to Lake Bonaparte the syenite projects out into the valley about an

eighth of a mile, apparently cutting out all of the fine grained gneiss together with much limestone, but lack of outcrops again prevents a positive conclusion. Beyond this point the boundary of the syenite is vague and no structural data of importance are shown within the limits of this season's work.

East of Harrisville and about a mile south of Pitcairn forks, near the road leading to Goose pond the syenite boundary is again shown and while the actual contacts are covered the break in outcrops is only a few feet and does not suffice to hide some important facts. The syenite appears a few feet south of a good outcrop of limestone and again just north of the latter. The limestone is filled with coccolitic bands and irregular masses of feldspar of peculiar green and purple tints. The whole aspect of this small outcrop of limestone suggests that it has been much altered by contact with metamorphism and it resembles closely some of the typical contact zones of the region. The limestone of the main mass a few rods to the north is on the other hand of the normal character.

The writer would interpret this locality as another intrusive contact, the small area of impure limestone being an inclusion caught in the syenite. But from the description given it is evident that the data are far from conclusive and are capable of totally different explanations. It is only when taken in connection with other localities that this one has a value chiefly confirmatory.

On making a comparison with the phenomena shown near the station one important point is brought out. At the latter locality the syenite is generally in contact with a narrow band of gray gneiss, north of which limestone extends for a mile or thereabouts across the strike. At the locality just described on the other hand the syenite is in contact with the limestone itself, and continuing northward there is a series of alternating limestones and fine gneisses quite different from that at the other locality. This appears in the following figure of a roughly made section about a half mile in length. Thus it is evident that the syenite is in contact with different parts of the limestone formation in

Plate 5

INCLUSIONS IN SYENITE

different places, a fact which falls perfectly into line with the other structural data thus far accumulated.

Fig. 4 Contact of syenite and gneiss series. Length of section one half mile.

A further and even more striking illustration of the relation just brought out appears on the examination of exposures about one and one half miles east of the last locality where the road from Pitcairn forks to Jayville runs close to Jenny creek. Beside a waterfall and dam in the creek there is an excellent exposure of the syenite in contact with a fine, well laminated, dark gray gneiss. The contact is very sharp and there is no gradation between the two rocks though the syenite is as usual gneissoid with foliation parallel to that of the fine gneiss. The syenite forms lenses elongated in the direction of foliation and also irregular masses cutting across the foliation of the gneiss.

The width of the lenses varies greatly as does that of the gneiss between adjacent lenses and sharp inclusions of the gneiss occur in the syenite. The phenomena are all exhibited with great clearness in a section parallel to the strike, and after a most careful

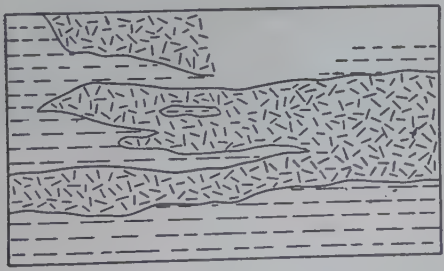


Fig. 5 Contact of syenite and fine gray gneiss presumably of the limestone series. The section is parallel with the strike and is about 25 feet in length.

examination the writer found it impossible to arrive at any satisfactory explanation other than that of the intrusion of the syenite into the gneiss. Fig. 5 is taken from a field diagram of this

strike section. (See also pl. 6) The dip section is not well shown but as far as it can be seen corresponds precisely in its nature.

On the whole this locality presents as strong evidence in regard to the true nature of the syenite as has been found anywhere. To be sure the syenite here exposed is not continuous at the surface with the main body of the rock, but the latter appears only a few rods away and the material of the lenses is absolutely identical with it.

As intimated above, the rock cut by the syenite is of interest when compared with that cut at the previously described localities. At the first locality, it was a fine grained gneiss, with minor limestone, at the second it was limestone, here it is gneiss again but quite different from that of the first locality, being darker colored, more varied and in much greater amount.

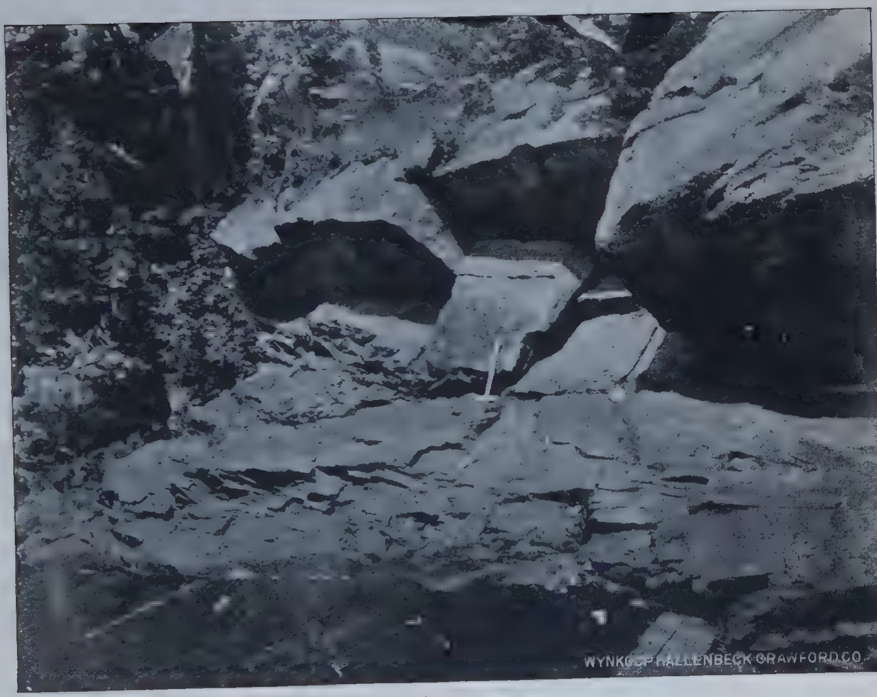
At the first locality the gneiss was a rather narrow band overlaid by heavy limestone but here the gneiss is very thick continuing for several rods across the strike with no limestone showing, though the highly pyroxenic character with some calcareous fragments almost if not quite in place make it practically certain that this gneiss is also of the limestone formation.

So in addition to the striking phenomena presented by the different localities singly we have a supplementary, large structural feature afforded in the contact of the syenite with different horizons of the limestone formation.

Taking all of these structural data together they seem sufficient to prove beyond doubt that the syenite is a plutonic igneous rock, and the petrographic and chemical characteristics of the rock so far as they have been investigated are entirely in harmony with this view.

While at one time the gneissic structure would have been regarded as positive evidence of sedimentary origin, at the present day it is quite unnecessary to advance any argument to prove that this is not the case, as such a structure is now known to have no necessary connection with bedding and to be quite as common in igneous as in sedimentary rocks. As to its origin in the present instance, the cataclastic structure which develops to a

Plate 6



SYENITE-GNEISS (PITCAIRN) CONTACT

marked degree as foliation becomes more perfect indicates that the latter is a product of crushing subsequent to solidification.

Nevertheless the writer is inclined to think that flow structure is also present, though the secondary structure has made it difficult to prove that such is the case except in some minor instances like that connected with the inclusions first described.

It is the fact that this rock of wide exent is distinctly gneissoid and yet shows its origin clearly that has led the writer to deal with it at such length; for the western Adirondack region is largely made up of gneisses which have much in common with this rock, and any localities where determinate structural data are available demand close study, much closer indeed than has yet been given in any instance. So far as the studies have been carried on the only rocks found which closely resemble the great areas of gneiss and whose origin is fairly clear are those which are certainly or probably of igneous origin. On the other hand, the gneisses which from their mode of occurrence, structure and composition are almost certainly of sedimentary origin are very different as a class from the gneisses of the large areas above referred to.

The bearing of these facts and the inferences to which they lead have been discussed in a previous report. But while the conclusion that some of the gneisses are certainly and most of them probably igneous seems fully justified in the present state of the inquiry, the writer constantly endeavors not to give undue prominence to this view in dealing with the facts in hand. It is adopted as a finality only when, as in the case under discussion and in others previously described, it affords a rational explanation of phenomena that can be correlated and accounted for by no other hypothesis.

The southern margin of the syenite is much less clearly defined than is its northern margin where it comes in contact with the limestone formation. Passing southward from the latter the syenite at first slowly and irregularly then more rapidly increases in gneissoid structure till at a distance of from three to five miles from the limestone a region of red hornblende gneiss is

reached. The relation between this rock and the syenite has been carefully sought but as yet not conclusively established for the whole area. West of Natural Bridge in Jefferson co. the syenite unquestionably passes over into a very perfect red gneiss as described in the paper so often cited. Both in the field and under the microscope the gradual change of the rock can be followed through every step. But in the region now under discussion the phenomena, while conclusive in regard to some parts of the gneiss, are not so for others. From field evidence it is clear that the hornblende gneiss adjacent to the syenite is merely a modification of the latter rock, the passage between the two being quite gradual with no break of any kind. Often the typical red gneiss contains large feldspars identical with those of the syenite and evidently a residue from crushing. These portions of the hornblende gneiss together with the Natural Bridge occurrences afford instructive examples of true igneous gneisses younger than the limestone series.

But farther south toward the Diana-Croghan line and in the latter town there are large areas of red hornblende gneiss, coarser, more massive and more quartzose than the gneisses clearly derived from the syenite. They more closely resemble slightly modified hornblende granites, and indeed at some points, as for instance Jerden Falls, are nothing but hornblende granite so far as structure and composition are concerned. While there is no doubt that the syenite passes into typical gneisses on a large scale, it is as yet uncertain whether these extensive areas of coarse hornblende gneiss to the south and east are derived from it or belong to a separate period of intrusion. In either event there is doubtless a close relationship between the rocks.

These coarse and rather massive gneisses were found by Mr D. H. Newland, working under the writer's direction, to continue without perceptible break into southeastern St Lawrence co. beyond Cranberry lake and northward into the towns of Russell, Pierrepont and Parishville, constituting a very large area. Occasionally finer banded gneisses probably sedimentary appear. and a garnetiferous amphibolite similar to that of Warren co.

occurs just north of Cranberry lake. At Clifton mine the schists and lean ore are of such a character as to indicate that they belong to the limestone series, though no actual limestone was found. That a more detailed study of the region will show the presence of small, scattered areas of the limestone series is practically certain. But the region as a whole is gneissic and affords a good illustration of the large scale on which the gneisses of plutonic habit occur. Throughout the whole area with the exceptions already noted the gneisses exhibit their usual character, being quite uniform, massive, with almost no banding and the foliation striking northeast and dipping north.

While it is probable that small isolated intrusions of gabbro occur, the absence of any large areas of this rock is noticeable and of considerable importance, as will be noted below.

Before passing to the consideration of other topics it may be well to sum up the important points which make the syenite of particular interest. It is a rock of considerable extent, covering not less than 75 square miles, is of igneous origin and younger than the limestone. But while its "habit" is usually igneous and its origin would be suspected aside from all structural data, the syenite is nearly always gneissoid and passes over into a typical hornblende gneiss, unquestionably a product of dynamic metamorphism. Though commonly gneissoid, the syenite lacks distinct banding except in a few localities, where this structure is associated with basic segregation or with inclusions. While the rock is somewhat variable in composition, the variations take place very gradually and on the whole the composition is quite fixed over wide areas.

All of these phenomena are what would be expected in a gneiss of igneous origin, and it is important to find them so well exemplified in this rock whose origin is clear.

In gneisses of sedimentary origin on the other hand, pronounced banding with frequent and sudden changes of composition at right angles to the strike are to be expected. The limestone formation furnishes abundant examples of the latter class, while, as stated in a previous report, the wide areas of gneiss so

frequent in St Lawrence and Lewis counties conform in every way to what would be expected of igneous gneisses.

As in many cases direct evidence will probably never be found to prove the origin of these gneisses, it will be necessary to arrive at conclusions in regard to the problem by the study of analogous rocks, which like the syenite give evidence of their origin. From what has thus far been done in the region the writer believes that close study of typical examples of igneous and of sedimentary gneisses will furnish data on which, in most cases, wholly justifiable conclusions as to origin may be based. But there will always remain a group of intermediate character whose origin will be doubtful. New and more refined methods of investigation may narrow the limits of this group, but that it will ever be obliterated seems at present improbable.

As stated in the beginning of this report, there is a marked contrast between the rocks on the northern and southern sides of the Diana-Pitcairn limestone belt. The former region shows great variety, the latter much sameness. No effort has been made to straighten out the tangle of intrusive rocks, igneous and sedimentary gneisses and limestones which appear in the irregular hills, cliffs and minor valleys north of the limestone belt. On the whole the area bordering on the belt and extending back three or four miles is the most varied and complex that the writer has seen in the Adirondack region. To map it with any approach to accuracy will require a large scale base-map and much careful work. Only a few facts need be recorded here, and, owing to the very brief examination of this portion of the region, they are quite disconnected.

About two miles north of Harrisville the Gouverneur road crosses Jenny creek. Just beyond the crossing a good granite limestone contact is exposed in the road, while to the east a high, steep ridge of gray granite rises. While consisting essentially of granite, the ridge shows numerous outcroppings of limestone scattered irregularly over it. These patches of limestone are clearly inclusions in the granite and are more or less affected by metamorphic agents. In general the grain is very coarse

and this is sometimes accompanied by a beautiful blue color. Less often though by no means rarely, typical contact zones, in which pyroxene is the most abundant mineral, are developed. Occasionally inclusions of the fine pyroxenic gneisses of the limestone formation may be found analogous to those shown in the syenite. Abundant veins of pegmatite and quartz doubtless represent the last stages of igneous activity at this point.

Half a mile west of this locality, across the Oswegatchie river is a bold hill made up chiefly of gabbro which was described at some length three years since.[a]

This same rock has been found in scattered areas of smaller extent two miles or more to the westward. In these occurrences it is often extremely coarse and very basic, looking almost black at a short distance. In the field it would be taken for a basic diorite, but in thin section shows prevailing pyroxene, though hornblende is always present and sometimes in preponderance.

These outcrops usually show a marked gneissoid structure and the true nature of the rock might be a matter of doubt but for the outcrops referred to above where the intrusive character is plain. The tendency of these intrusions to assume the form of greatly elongated lenses or schists, combined with the gneissic structure of the rocks, is apt to lead to confusion in distinguishing between intrusive and interbedded gneisses.

A good illustration of this difficulty is afforded by a section shown just south of the new sawmill a half mile west of Gier's.

The actual outcrops cover about one eighth of a mile, the whole section being about one half mile in length. Starting on the north there is a heavy well-banded garnetiferous gneiss with a lens of gneissoid gabbro. Below this is limestone with lenses of granite sometimes massive and sometimes extremely gneissoid. Whether there is som fine, acid gneiss of different origin here too, or whether it is all granite, is open to question. After a wide break another large mass of gneissoid gabbro appears.

In this section the limestone and granite are readily classed as sedimentary and igneous respectively, but with doubt as to

[a] Crystalline limestones and associated rocks of the northwestern Adirondack region, Bull. geol. soc. 6:268-70.

part of the latter. The gabbro occurs quite like an interbedded basic gneiss, but is clearly the same rock seen elsewhere as an intrusive, so that its character is fixed by indirect evidence. Finally as to garnetiferous gneiss, we have no single positive piece of evidence to determine its nature, but it can be traced for several miles along the strike, appearing to be a definite horizon in the limestone formation; it is well-banded and quite variable in both composition and structure; it does not at all resemble in its appearance an igneous rock, while it is quite like a great many other garnetiferous gneisses which have been seen in the region, always closely associated with limestone. In view of all of these facts it seems highly probable that this garnetiferous gneiss is of sedimentary origin, a constituent member of the limestone formation.

It is of interest to note as confirmatory of this view that in thin sections it is seen that the order of crystallization in the gneiss is not that normally present in igneous rocks. Instead the ferromagnesian mineral, mica, was the last to form, wrapping around and including quartz, feldspar and other constituents. The mica moreover is the golden brown phlogophite variety so common in the limestone.

It need hardly be stated that no great reliance is placed on this structure as an indication of origin, for not only does the order of crystallization vary, but in a region of intense metamorphic action like this the order might be and indeed certainly has been in some cases entirely changed by recrystallization.

Nevertheless it is interesting when taken in connection with the other facts regarding the gneiss and may prove of value if found to be a rule. Already this inverted order of crystallization has been noted in several gneisses which like the present one give many indications of being sedimentary.

FULTON CHAIN AND RAQUETTE LAKE AREA

As nearly all the work hitherto done in the western half of the Adirondack region had been in the marginal portions of the crystalline area, it seemed advisable to make a trip into the heart of the region and take the first steps toward bridging the gap that

has existed between the writer's work on the west and that of Professors Kemp and Cushing on the east. As above stated, it was farther desired to settle if possible the question of the existence of a great core of gabbro, which has been assumed to make up the central part of the region. Hamilton co. being practically unknown from a geological point of view, except for a few facts published by Emmons and some work done by the writer several years since, and the same being true of central and northern Herkimer co. it was decided to examine the region contiguous to the Fulton chain of lakes and Raquette lake in these counties.

This work as carried out gave a section across Herkimer co. and well into Hamilton co. and passed through the hitherto unexplored area lying in the heart of the Adirondack region. In consequence, while the work was in the nature of a hasty reconnaissance and few details were gathered, the broad facts established are of very considerable importance in their bearing on the geology of the Adirondack region as a whole.

Approaching this area along the line of the Adirondack and St Lawrence railroad the first outcrop of crystalline rocks is seen in the bed of Woodhull creek about an eighth of a mile north of the Forestport station. The rock is a rather massive, coarse, hornblende gneiss and when freshly blasted is of a deep gray color with a slight greenish tone. The grain is quite variable, and coarse, almost pegmatitic areas are seen with some quartz veins. The strike is northeast.

This rock continues two or three miles north and then a pink gneiss mingled with gray comes in. Two and one half miles north of White lake a quarry has been opened in a high, steep ridge, round the northeast end of which the railroad runs. The rock is an acid gneiss in various pale tints of pink, green and gray and often contains large bunches of garnet (pl. 7).

Most of the outcrops shown along the railroad as far as Fulton Chain station consist of either pink or gray massive gneiss, though some dark, more schistose rocks occur in small patches. Similar rocks are crossed in driving from Fulton Chain to Port Leyden in the Black river valley, the coarse massive gneisses pre-

vailing, but the finer gneisses coming in occasionally. At and near Moose river well banded fine gneisses and rusty gneisses strongly suggest the limestone series, though in the hasty examination made no limestone was seen.[a]

At Fulton Chain station a ridge of reddish gneiss is shown west of the track. The rock is sometimes quite massive and again well foliated with strike n40°e and dip 25°n. A few rods north of the station in this ridge is the mine which furnished the ore for the forge which has given the name to the neighboring hamlet of Old Forge. Though the ore deposit is of surprisingly meager dimensions to have led to the investment of considerable money, even under the conditions existing nearly a century ago, it is not without interest.

The opening is broad and low, of slight depth but sufficient to expose the ore well. At this point the rock of the ridge is very massive, having all the appearance of a medium grained, red hornblende granite. Irregularly scattered through this rock and shading into it by imperceptible degrees are areas of fairly coarse pegmatite. These areas are sometimes vein-like in form but quite as often entirely irregular, and their gradual blending with the country rock is so marked that it seems hardly possible to regard them as intrusions. While sometimes highly quartzose, the pegmatite is more generally marked by a great predominance of feldspar in roughly bounded crystals. Under the microscope this feldspar is shown to be an acid plagioclase.

Filling the interspaces between the feldspars or the feldspar and quartz is magnetite, which serves as a sort of binding material to hold together the other minerals; and it is this rock that constitutes the ore. In the dump specimens as well as in the walls of the mine the magnetite is a decidedly minor constituent of the pegmatite, which is itself in limited amount. So the ore is very lean and forms a limited and irregular body in a hard wall rock. But as the proportion of magnetite varies widely and occasional lumps are comparatively rich, it is probable that a little fairly good ore may have been taken out.

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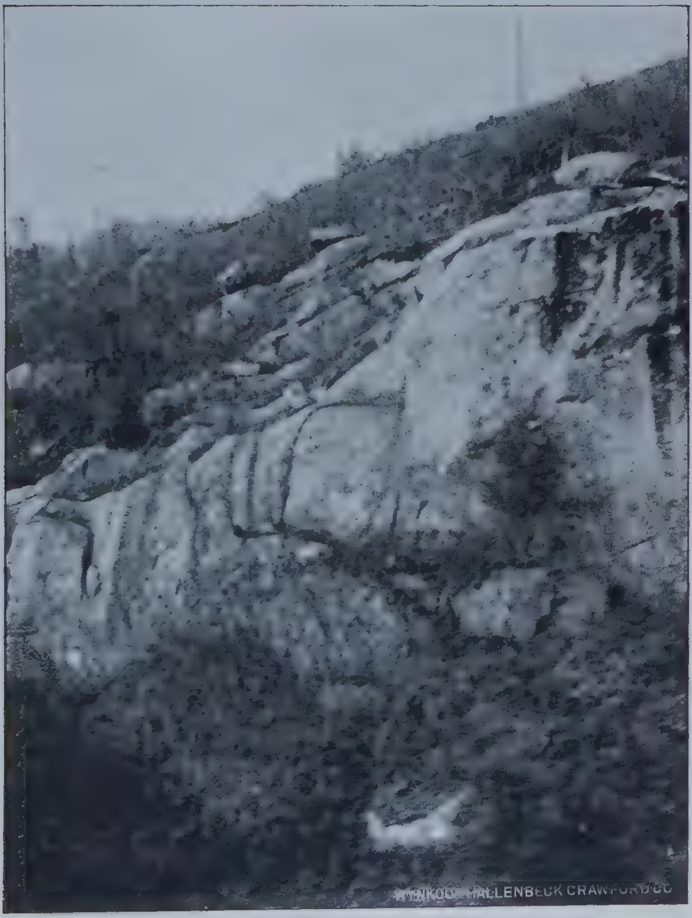
[a] Since the above was written Mr D. H. Newland has found a little impure limestone at this point.

Plate 7



ACID GNEISS, WHITE LAKE

From the genetic point of view the ore presents an interesting but troublesome problem. The basis of known facts is so meager as to make any conclusion very hypothetical, for even the nature of the country rock is uncertain. But whether this rock is igneous or a very intensely metamorphosed sediment, it seems to the writer that we are forced to about the same explanation for the ore body.

Assuming the rock to be as it probably is igneous, the structure, composition and mode of occurrence of the pegmatite are opposed to the idea that it is a strictly primary igneous segregation. Instead it is much more likely to have resulted from the action of hot solutions, aided perhaps by vapors, acting during the cooling of the rock.

If on the other hand the country rock is of sedimentary origin, it has undergone such intense metamorphism as to be converted into a rock having all the structural peculiarities of a granite. Even if such a complete change can be effected without fusion, it can hardly result without the production of much heat and in consequence heated solutions would play an active part in the process of crystallization.

It is to these solutions that we must look for the formation of the ore deposits, and thus we are led to accept a process quite similar to that first suggested. In either case the ore is regarded as concentrated by hot solutions from the immediately adjacent rocks.

That the ore was formed by one of the processes mentioned and most probably by the first seems to the writer a natural and justifiable inference from the phenomena presented in the deposit, though with the scanty data at hand it is impossible to follow the process in detail or even to be certain of its truth in a general way.

It is interesting to note that with this as with the other magnetite deposits thus far seen in the western Adirondacks there is nothing to suggest its origin as a contact deposit where gabbro is intruded into gneiss, as Prof. Kemp has shown to be probable in the case of the large bodies of magnetite in the gneisses

of Essex co. The western magnetites are so far as seen either portions of the country gneiss abnormally rich in magnetite and shading off on all sides into the ordinary rock, showing no well defined ore body and with no associated intrusive masses, or they are simple segregations of magnetite in an igneous rock, such as those in the syenite of Diana and Pitcairn above described. The latter are of course analogous to the titaniferous magnetites of the gabbro areas in Essex co. though on a much smaller scale.

From Fulton Chain station a reconnaissance was made to the southeast, east and northeast, embracing the region about Little Moose lake, Lime Kiln creek, and Lime Kiln, Fulton Chain, North Branch, Big Moose, Raquette and Forked lakes. This examination gives in addition to previous work a section of considerable width, extending from the Black river in Lewis co. across Herkimer co. and half way across Hamilton co. Throughout this lake region there is, excepting a few localities to be referred to later, a great uniformity in the geology and the area may be briefly described as a whole.

The prevailing rock is a medium grained hornblende gneiss, closely resembling that described as occurring at Forestport. In ordinary weathered exposures the rock is light brown, but when fresh is a deep gray, sometimes with a greenish tinge, or a pale red, the passage from one color to the other being quite gradual. While foliation is usually shown, it is seldom very perfect and massive phases are common. Banding though occasionally present is a decidedly exceptional feature. The foliation strike is prevailingly northeast though exceptions are not rare, and the dip when shown is usually to the north.

The most pronounced feature of this rock is its uniformity over wide areas, the utmost sameness being presented in a very large percentage of the outcrops seen throughout this region. It is well shown at many points along the shores of the lakes and on the neighboring mountains.

The same unformity marks the rock as seen in thin section. It is an aggregate of microperthitic feldspar, quartz and deep

Plate 8

FELDSPATHIC CRYSTALLINE LIMESTONES (PSEUDO-CONGLOMERATE). ROCKY POINT, FOURTH LAKE, FULTON CHAIN

green hornblende, with accessory zircon, magnetite, etc. Not uncommonly a grayish green, monoclinic pyroxene appears with or instead of the hornblende, and biotite is occasionally present. The microperthite rarely gives place to a plagioclase feldspar. The quartz is on the whole the most variable mineral as to quantity, usually being present in abundance but sometimes quite inconspicuous. Cataclastic structure is notably rare, having been obliterated if ever present by recrystallization.

Gneissic rocks differing in a more or less marked degree from the last occur on a small scale, and in some cases are doubtless peculiar modifications of the hornblende gneiss, while in others they must be regarded as quite distinct. Of the latter class is a very dark colored rock outcropping on the recently constructed road from Fourth lake to Mohican lake about two miles west of the latter. This rock is composed of strongly pleochroic hypersthene and basic plagioclase with an abundance of garnet. In mineralogical composition therefore it is garnetiferous norite, but as its structural relations are unknown it can not be classed as an igneous rock, being more probably a member of the limestone formation.

Another gneiss that appears to be totally distinct from the prevailing hornblende gneiss occurs on the long point jutting out from the western shore of Raquette lake. This is a rather fine grained rock made up of thin alternating pink and green bands. Nothing could present a greater contrast to the massive, uniform gray gneiss and it is such a contrast as seems to demand the recognition of the two rocks as entirely different formations. Still other types of gneiss appear, but those only need be described which occur in connection with the crystalline limestone which has been found to have a considerable development in this region.

In a previous report the writer stated that, while in passing from the large limestone belts of St Lawrence co. toward the southeast the amount of limestone decreased, it was probable that scattered areas would be found all through the Adirondack region. This is borne out by the presence of several such areas

in the region now under consideration. Typical crystalline limestone has been found in rather small quantities at the head of Fourth lake, on the north shore of Sixth lake, on the island in Seventh lake, on the west shore and the island of Eighth lake, on Lime Kiln creek and on the east shore of Raquette lake. Rusty gneisses like those of the limestone formation but not accompanied by any actual limestone have been found at two points between Seventh lake and Mohican lake, on Lime Kiln lake and at Moose River.

In view of the fact that the limestone on account of its ready solubility is apt to be very inconspicuous, and that only a rapid reconnaissance of the region was made, it is certain that other limestone areas occur and that it is by no means a rare rock.

Perhaps the most typical development of the limesone is on Lime Kiln creek southeast of Little Moose lake near the logging dam. The limestone here is coarse and fairly pure though penetrated by a great deal of pegmatite. Rusty gneiss is present, much contorted, and the whole association and structure is precisely like that of the limestone belts of St Lawrence co. At the logging dam there is exposed a well banded, fine gray gneiss which would be suspected of belonging to the limestone series, even if the limestone itself did not appear in the immediate vicinity.

About half a mile down stream from this point at the mouth of a small brook there is an outcrop of mica schist and a highly quartzose rock, the two apparently bedded rocks of sedimentary origin. Thin section shows these rocks to be, the one of true mica schist, the other an impure quartzite containing much pyroxene, zircon, etc. No equally good examples of these two types of metamorphosed sediments have been seen by the writer anywhere else in the Adirondack region. The presence of the limestone five or six hundred feet up the brook, showing the same strike and dip (n40°e, 45°n) as do the schist and quartzite, tends to substantiate the conclusions as to the sedimentary origin of the latter. The facts observed in this vicinity indicate the

Plate 9

FELDSPATHIC CRYSTALLINE LIMESTONE, WITH LARGE INCLUSIONS. ROCKY POINT, FOURTH LAKE, FULTON CHAIN

presence of quite an extensive belt of the limestone formation which should be traced in detail.

Rocky point and Goethe's point at the head of Fourth lake present a variety of the limestone totally different from any that the writer has elsewhere seen. The limestone with associated gray and rusty gneisses occupies only a small area and might easily be overlooked did it not form the shore of the lake for a short distance. On a weathered surface the rock presents at first glance a marked resemblance to a fine conglomerate, with the pebbles projecting above the more yielding cement. But on closer inspection the pebbles resolve themselves into crystals of feldspar from a quarter of an inch up to one or two inches in diameter, while the cement is fine crystalline limestone containing much pyroxene.

It is evident that the feldspars are not residual but a product of crystallization in situ. For not only can no foreign source be discovered for them, but their angular form, unity of character and relation to other minerals show their autogenic nature. The limestone also shows large angular and rounded masses of schist and pyroxene gneiss scattered through it, which further recall the appearance of some conglomerates. But it is evident that these fragments are identical with the schists and gneisses of the limestone formation itself, and when the breccias and pseudo-conglomerates of the limestone of St Lawrence co. are recalled, it is clear that this is an extreme case of the same kind. The formation has been subjected to pressure sufficient to crush the imbedded gneisses and schists and mingle the fragments with the flowing, putty-like limestone.

The appearance of the feldspathic limestone is shown in plate 8. The peculiar "pebbly" aspect is evident, while at the same time the very characteristic surface produced by weathering is quite as apparent as in a normal crystalline limestone. The pseudo-conglomerate is shown in plate 9, which also affords a nearer view of the feldspathic limestone.

In addition to the peculiar feldspathic limestone described there is a good exposure of typical limestone associated with

micaceous and hornblendic schists on the point a few rods east of Rocky point. The normal weathering with smooth rounding surfaces with the formation of small crevices by solution is well shown in plate 10.

The island near the south shore of Seventh lake is made up of rusty and well banded gneisses with some highly impure quartzose limestone. In the rusty gneiss are thin beds of chondroditic limestone. This is a rare rock in the western Adirondacks, having been previously found so far as the writer is aware only in the town of Rossie, St Lawrence co. In the present case the chondrodite is of a rich reddish brown color, and is very abundant, affording a rock of a beauty seldom surpassed.

The rusty gneiss also contains many lenses and veins of coarse calcite rich in quartz, mica, pyroxene, etc. This calcite dissolves with a very smooth surface, quite unlike the rasp-like surface commonly shown by weathered crystalline limestone, and as a result of this solution the gneiss is full of cavities containing the loosened silicates, etc.

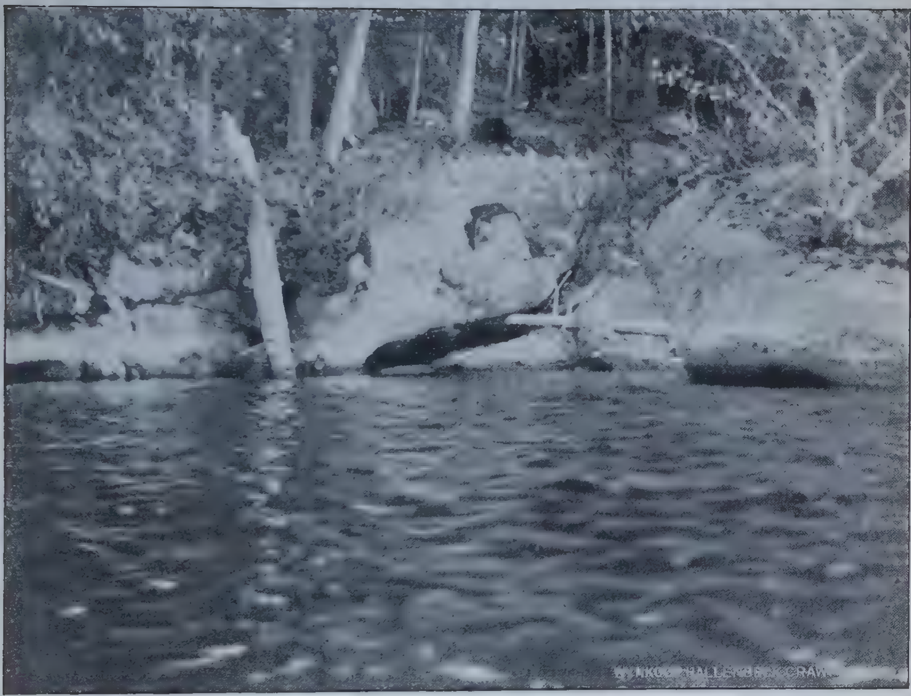
Layers of almost pure, gray tremolite are shown and other layers are highly micaceous. Graphite is abundant through the rocks, while veins, lenses and irregular masses of quartz and pegmatite are present in great quantity.

While there is some variation in strike and dip, the ordinary northeast strike and steep northerly dip predominate. Plate 11 shows this locality as seen from the lake.

The great variety of rock shown here illustrates in a striking manner the general rule that the gneisses which are of undoubted sedimentary origin vary widely within narrow limits and retain much of their original bedded character. But even here there is not lacking an element of uncertainty; for there are present two layers or lenses of fine, pink granitic gneiss, quite unlike the other gneisses and in every respect resembling an igneous rock. That it is such is extremely probable and yet the structural data presented are not sufficient to establish the fact.

Rusty and gray banded gneisses also appear on the adjacent south shore and on the north shore near the outlet, and, though

Plate 10



Corroded crystalline limestone. Rocky point, Fourth lake, Fulton chain

no limestone is present, there can scarcely be a doubt that these gneisses belong to the limestone formation.

On the west shore of Eighth lake and on the island are good exposures of a typical crystalline limestone, rich in mica, pyroxene and graphite. The usual gray and rusty gneisses with a coarse amphibolite are present but are not well shown.

The only limestone seen on Raquette lake is located at the end of the long point just south of Marion river. The limestone itself is in very small amount and quite impure but the rusty gneiss has a very considerable development.

As already stated no other occurrences (with a single exception to be mentioned below) of actual limestone have been found, but the formation is probably represented as indicated on the map by rusty and well banded gneisses at several points.

From the foregoing it is evident that the limestone formation has a very considerable development in the region under consideration and that it corresponds closely in character with the limestone formation of St Lawrence co., though so far as seen there is a relatively larger amount of the associated gneisses and schists, and the limestone itself is decidedly less pure. While it is natural and for working purposes convenient to assume that the limestone formations of the two areas are essentially the same, the fact must not be lost sight of that this assumption will perhaps never be proved true. And even with this condition the assumed equivalency must not be considered as analogous to the equivalency of different areas of a paleozoic or later limestone, but rather as meaning a deposition at not greatly separated intervals with a subsequent history essentially identical.

From the data presented above it is clear that this considerable area in the very heart of the Adirondack region is made up essentially of gneiss, with minor quantities of crystalline limestone and its associated sedimentary gneisses and schists.

While local variations come in, all of these rocks show a prevailing northeast strike and northerly dip. This is entirely analogous to what is shown in St Lawrence, Jefferson and northern

Lewis co., though there the limestone is more abundant and there is a greater variety of rocks.

A considerable area in southwestern Hamilton co. examined by the writer some years since is made up almost entirely of a gray gneiss practically identical with that of the lake region here described and having the same prevailing strike and dip. We have thus three areas stretching entirely across the western half of the Adirondack region, one at the north, one at the south and the third midway between, and in all of these areas the rocks are essentially gneisses with more or less limestone, and always with a prevailing northeast strike. So far as the writer is informed these facts fall closely in line with the results obtained by Professors Kemp and Cushing on the east and lead indubitably to the conclusion that the Adirondack region, instead of consisting of a great central mass of gabbro surrounded by a narrow fringe of gneisses and limestones with quaquaversal dip, is essentially composed of gneisses with numerous limestone belts, having northeast strike and north dip, and cut through on the east by immense intrusions of gabbro. It is still possible of course that some areas of gabbro may be found in the unexplored portions of the western half, but even should this be so it would not materially modify the above conclusion, as they must necessarily be isolated intrusions of no great extent, rather than parts of a large area. Very small intrusions of gabbro have been as a matter of fact found in abundance, and the writer has thought that they were derived from a central core, but this supposition must now be abandoned and these gabbro intrusions recognized as quite independent phenomena.

The foregoing accentuates the fact emphasized by the writer in his last report that the great problem of the Adirondack region lies in the origin of the gneisses and their relations to the limestone formation. As to the importance of this problem it is only necessary here to add that it is if possible increased by the establishment of the great area which these rocks occupy.

On this problem the facts above enumerated have a bearing though they are far from affording a solution. That some of the

Plate 11

BANDED GNEISS OF LIMESTONE SERIES, WITH MUCH PEGMATITE. ISLAND, SEVENTH LAKE, FULTON CHAIN

gneisses are igneous and others sedimentary is assumed to be proved and examples of both kinds have been cited. But in the gray hornblende gneiss of the lake region we have a great formation of whose origin nothing is known from direct and positive evidence.

That it is part of the limestone formation the writer finds it difficult to believe in view of its extreme uniformity and lack of banding, in both of which respects it is totally different from the gneisses which evidently belong with the limestone.

This uniformity together with the composition and structure of the gneiss seems to the writer to indicate with great probability an igneous origin. This idea is strengthened on comparing the rock with the syenite gneiss of Diana above described, the two rocks being somewhat similar in composition and structure. Pointing in the same direction are the facts presented on the north shore of Sixth lake, where in a steep cliff the limestone is cut through and through with typical intrusive contact zones by a granite which runs over into gneissic facies closely resembling the hornblende gneiss. Nevertheless this rock is not continuous at the surface with the main mass of the hornblende gneiss, and so, while the occurrence is suggestive, it is far from conclusive. At no other point is there any direct evidence as to the relations between the limestone and the gneiss.

Thus, while in the writer's opinion, this great formation will in all probability prove ultimately to be of igneous origin, the evidence thus far obtained is clearly insufficient to establish beyond question that such is the case.

HAMILTON COLLEGE, CLINTON, N. Y.
February 1898

PRELIMINARY REPORT ON THE GEOLOGY OF WASHINGTON, WARREN AND PARTS OF ESSEX AND HAMILTON COUNTIES

By J. F. Kemp and D. H. Newland

1897

JAMES HALL, *State geologist*

SIR—I submit herewith a continuation of my previous reports upon the crystalline rocks of the eastern Adirondacks. The former papers have dealt exclusively with Essex co. In the present one the work has been done in Washington, Warren and Hamilton counties, and in a small part of Essex, which I had not previously reached. The field work has been chiefly performed by Mr David H. Newland, B.A. acting under my general directions. During a part of the time Mr Newland was assisted by Mr B. F. Hill, B.A. I spent a week with the former in the complex area around Whitehall, but aside from this and from some reconnaissance trips through Warren co. in previous summers, the report though written by myself is based upon his observations.

Very respectfully yours

J. F. KEMP

CONTENTS

ILLUSTRATIONS

INTRODUCTION—OUTLINE OF GENERAL RESULTS

By J. F. Kemp and D. H. Newland

The field work for the accompanying report was done in August, September and October 1897. It was chiefly performed by Mr Newland, acting under the general direction of Prof. Kemp by whom the report has been finally written. The area joins that portion of Essex co., lying to the north, which has already been reported upon,[a] and it is our intention to complete if possible in 1898 the mapping of the crystalline rocks to the fringe of paleozoic strata on the south.

One of our chief objects, specially in the northwestern portion of the region here described has been to determine the southern and southwestern limits of the Norian series of labradorite rocks. Our work has proved that on the southwest so far as we now know, they do not cross the Essex co. line, but are succeeded by the usual gneisses and crystalline limestones. This will appear at once from the geologic maps submitted herewith. We have found them on Moose pond, on Mt Santanoni and on Cold river near the Preston ponds, but to the west and south, beyond these points they soon die out. Inasmuch as they are reported to reappear at the gorge of the Mohawk at Littlefalls, there are probably other small areas in the intervening wilderness, but we do not anticipate extended developments.[b] Prof. Smyth's work will throw light on this question in time. This statement refers specially to those rocks which are chiefly labradorite (i. e. the anorthosites). The basic gabbros we have found in wide distribution and some of our gneisses as later set forth may belong with the Norian rocks.

As a result of the field work on which this report is based and of the subsequent study of thin sections of many of the rocks as

[a] J. F. Kemp. Preliminary report on the geology of Essex co. 15th annual report of the N. Y. state geologist, 1895, p. 575-614.

[b] A small area was discovered by Mr Newland in 1898 in the northwestern corner of Warren co.

well as of the experience which has been gained in Essex co. and of the work of Prof. Cushing on the north, some important advances have been made regarding the nature and origin of some of these puzzling gneisses. We have been impressed specially with the following facts:

1 Crushing and granulation of what were formerly massive and rather coarsely crystalline rocks have been excessive. The region of the crystalline rocks in Washington and Warren co. must have suffered extreme dynamic metamorphism. Finely granular gneisses were met repeatedly that were taken for quartzites at first, but which microscopic study shows to be crushed eruptives. The gneissoid structure has been super-induced upon them by these processes, and even uncrushed nuclei or lenticular eyes (Augen) have been destroyed. Apparently biotite has been prone to develop along some surfaces of displacement. In the exposures about Whitehall the crushing and granulation are specially marked.

2 Our knowledge of the geology of the region will be greatly advanced as soon as we can find the necessary evidence to prove what the gneisses were before they suffered metamorphism. In former reports mention has been made of gneisses of a general greenish color which have been found under the microscope to consist of microperthite in largest part, with which are varying amounts of quartz, brown hornblende, emerald green augite, hypersthene, plagioclase and small accessories. Varieties[a] rich in quartz have been met and again others with no quartz but with abundance of dark silicates. The commonest variety is near syenite in composition. These rocks have been very puzzling, because in the field they resembled gabbros so closely, whereas in the laboratory thin sections showed mostly microperthite, i. e. orthoclase, thickly penetrated with albite. They were specially cited when Ticonderoga township was described in the report for 1893, p. 452. All the varieties on the south were

[a] *See* Report, N. Y .state geol. for 1893, p. 452: petrography of series 1 in Ticonderoga; p. 470, North Elba, series 1.

observed to be so thoroughly gneissoid that the microperthitic structure was regarded, in accordance with widely prevalent views of it, as a result of metamorphism. Meantime an important memoir by F. Kolderup[a] has appeared upon an area of labradorite rocks near Soggendal, Norway, in which true igneous types containing microperthite and dark silicates in quantity, are described as associated with anorthosites; and Prof. Cushing has found them near Loonlake station, Franklin co.,[b] in perfectly massive form and containing angular inclusions of gneisses belonging to the series of the crystalline limestones. This latter discovery was a most important addition to our knowledge of the Adirondacks and has aided to clear up many obscure and puzzling facts which have been often observed by one of us (J. F. Kemp). The Loonlake,[c] Franklin co., rocks are regarded by Prof. Cushing, doubtless with entire correctness, as belonging to the eruptive series of which the labradorite rocks are the leading members, but as they are in highly gneissoid development in the area here described, and as they are far from the labradorite rocks, they are mentioned in the general series of gneisses. For convenience they will be called the "Whitehall type" of gneiss because they are abundant in Whitehall, just in the southwestern outskirts of the village, where they are quarried for underpinning. We may therefore safely refer to an original eruptive rock, all the dark green gneisses that have this mineralogical composition, however strongly foliated they may be now.

3 In a former report by one of us,[d] a coarse porphyritic rock of the general mineralogy of a diorite was mentioned. Somewhat similar ones were found in several places during the field work of 1897, but most important of all is a hill north of the village of Horicon, that is a coarse granite-porphyry. It has large pink, but thoroughly granulated phenocrysts of microcline in a rather

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a F. Kolderup. Die Labradorfelsen des westlichen Norwegens. Bergen's Museum's Aarbog, 1896, 5.

b H. P. Cushing Augite syenite near Loon Lake, N. Y. Read at meeting of Geological society of America, Dec. 1898. Bulletin of the society, 10:177.

c Loonlake, Franklin co., on the Chateaugay R. R. and the N. Y. C. R. R., is not to be confused with Loonlake, in Chester township, Warren co.

d J. F. Kemp. 1893. Remarks on Ticonderoga, p. 454.

coarsely crystalline ground mass of biotite and gray or green orthoclase, plagioclase, quartz, magnetite and a little pyrite.

Elsewhere we have often met augen-gneisses of this mineralogy, or with more or less quartz than the type, and we have been at a loss to account for them. The hill at Horicon has been quarried in some places for a massive granite, but to the north the massive rock passes over into an augen-gneiss. There is excellent ground for referring therefore many augen-gneisses elsewhere, to an original porphyritic eruptive of this character. The rock is called in the following pages the "Horicon type."

4 We have also discovered, and specially around Whitehall, excessively or purely quartzose gneisses or foliated quartzites that are quite certainly metamorphosed sediments. They form notable areas along the head of South bay, Whitehall township, and will be called the "South Bay type." Some feldspar is present, and more or less garnet, but the quartz is far in excess of any possible igneous rock, except a pegmatite that is almost a quartz vein. The exposures are too large for a pegmatite and they are associated with crystalline limestone. They are similar to the rocks described as quartzites by Dr F. D. Adams from the Laurentian areas of Quebec, as is shown by a comparison of specimens. These rocks have been elsewhere noted by the senior writer, in association with the crystalline limestones. There is also the peculiar graphitic quartzite at the graphite mines near Hague, Warren co. that must be noted as an additional Precambrian quartzite, of the highest stratigraphic significance.[a] It is fully described on a subsequent page, but we may note here also, the sillimanite-garnet gneiss, that lies over and under the graphitic quartzite as a rock not observed as yet in any other part of the mountains. We have been led by these exposures to a strengthened belief in the former presence of a great series of sedimentary rocks, which had been already indicated by the crystalline limestones, but in which from previous work we had seldom noted well-marked fragmental sediments. We are hope-

[a] *See* C. D. Walcott. Bull. Geol. soc. Amer. 10:227, pl. 22. This note appeared after the present report was sent in.

ful that in some localities, such as Whitehall (where we have made a beginning) and Minerva, that the stratigraphy can be worked out. But the problems need more detailed mapping than we felt that we could as yet give them.

The crystalline limestones themselves have been found in small exposures over almost all of Warren co. and generally in the crystalline belt of Washington. They are most extensive in Newcomb and Minerva townships of Essex, and to the south become thinner and more scattered. So far as we have observed they are less common in eastern Hamilton co. There is evidence to show that stratigraphical relations can be proven and that anticlines and synclines can be demonstrated.

5 Dikes of basic gabbro usually of moderate width, but lithologically like the larger masses in Essex co. have been met over a wide area—in fact in almost every township in Warren, but the basaltic traps almost disappear. Except for one or two south of Whitehall, the entire region here covered is barren of them. The anorthosites likewise fail,[a] as stated in the introductory remarks.

6 The paleozoic strata are only found as fringes around the crystallines or as setting short distances up valleys and not far from the larger exposures to the south, except in the Wellstown instance in southern Hamilton. This last named outlier was studied somewhat carefully by Mr Newland, but as it raised questions in his mind that required more attention than he was able to give them, in 1897, the subject is allowed to go over till our next report for its full elucidation. It may be premised that the evidence gathered still seems to us to indicate the advance of the Potsdam sea up a preexisting valley, rather than the exclusive infaulting of an otherwise widespread Cambro-Silurian mantle over all the crystalline area.[b]

7 Glacial striae have been noted in quite a number of places. They are almost always N 10 to 15 E, but they may be N and S, or as much as N 35 E. These directions are more northerly

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a Mr Newland found one area in northwestern Warren co. in 1898, which will be described in our next annual report.

b Compare R. Ruedemann. Amer. geol. Feb. 1898 p. 75.

than some that have been noted in Essex co. Terraces dating from the time of the retreat of the ice sheet are of marked development in both the Champlain valley and along the Hudson. Under the township geology we have remarked their presence and have cited the papers that have thus far been written, but the field is a practically unexplored one, and except for an occasional stray note, we have given it slight attention.

In southern Warren co. there is a peculiar tendency of the streams to leave the normal southerly courses and double back on themselves to the northeast again. This is pronounced in the case of the Sacondaga and the Hudson. The Sacondaga makes a very acute angle with its old direction, and the Hudson behaves in an almost identical way although it later resumes a southerly course. Prof. G. F. Wright, as subsequently cited under Whitehall, has noted an old channel of the Hudson leading to the south near Corinth, but regarding the Sacondaga we have no data to determine the diverting course.

In the following descriptions the same provisional names for the formations will be employed as in former reports. The stratigraphic demarcation between series 1 and series 2 is not sharp. The limestones may be but minor members, perhaps several times repeated in series 1, but they are lithologically distinct and peculiar. They are quite abundant in Warren co.

Series 1. Gneisses usually with both orthoclase or microperthite and quartz. Varieties with hornblende, biotite and pyroxene and with almost no dark silicate, are met. Plagioclase is usually present and may be the only feldspar. The exposures vary in color from very light gray, almost white, to dark gray or even to red. The foliation may be conspicuous or may almost fail. Two types of gneiss have been specially noted; the "Whitehall," usually dark green in color, and composed of microperthite, some plagioclase, varying amounts of quartz, emerald green augite, dark brown hornblende, often hypersthene, and sometimes garnets; the "Horicon", light colored augen-gneisses believed to have been derived from porphyritic granite like the one quarried at Horicon.

Series 2. Crystalline limestones, ophicalcites, black hornblendic and pyroxenic schists and thinly foliated garnetiferous gneisses. Rocks regarded as quartzites are also frequently associated. They exhibit quartz and augite with rather characteristic brownish yellow titanite.

Series 2a. Pronounced quartzites, with more or less graphite and usually with some garnets, and minor accessory minerals, constituting the "South Bay type."

Series 3. Dark basic gabbros, often passing into amphibolites from shearing. They form dikes and minor intrusions, cutting all the above.

Series 4. Paleozoic sediments, including the Potsdam sandstone, the Calciferous limestone, the Trenton limestone and the Utica slate.

Series 5. Trap dikes which may be in part or whole, Precambrian porphyries are not met in the area here described.

Series 6. Glacial and post-glacial gravels, sands and clays. Of these special attention has been only given to the Champlain clays.

Local geology by counties and towns

WASHINGTON CO.

The towns will be taken up in the following order, beginning on the north, Putnam, Dresden, Whitehall and Fort Ann. A small area of crystallines remains to be mapped in the southern part of the county.[a] All the eastern part of Washington co. is formed by the paleozoics, but we have given them but slight attention as they have already been outlined by Charles D. Walcott,[b] whose results have been incorporated in the state map.

Putnam

Topography. Putnam township lies on the high ridge between Lake Champlain and Lake George. It is practically a rocky neck, steeper on the side toward Lake George than on the one

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a This was mapped by B. F. Hill in 1898 and will be described in the next annual report.

b Charles D. Walcott. Taconic system of Emmons, and the use of the name Taconic in geologic nomenclature. Amer. jour. sci. Mar. 1888, p. 229, Ap. p. 307, May, p. 394. Plate 2, after p. 346.

toward Lake Champlain. The divides between the headwaters of the brooks are well over to the west, and the highest summits of the hills front immediately on Lake George. There are but two marked cross-passes, both of which are utilized by highways.

Series 1. The greater part of the town consists of gneisses belonging to this series. The prolongation of the ridge of Mt Defiance of Ticonderoga township, enters from the north, and terminates in Record hill and Anthony's Nose. The gneiss of Mt Defiance[a] is peculiar in presenting a marked igneous aspect, and in thin section exhibits microperthite, augite, hypersthene, hornblende and quartz. This is the "Whitehall type" of this report. The same type of rock continues into Putnam, but gneisses of a different character are also met. Much biotite appears and every evidence of intense compression and shearing is present. The feldspars are frequently white instead of green and the rock is often decidedly schistose. Gneisses of the composition of hornblende granites or of diorites and of more massive aspect are of wide distribution and others of a very quartzose character are richly provided with garnets. Just south of Wrights, a dark hornblende schist was found in the gneisses (spec. 40) probably representing a pinched intrusion of basic rock. The strike of the gneisses is quite variable. Near Wrights it is nearly north and south with an easterly dip, but elsewhere it is chiefly east and west, or a little north of west, but the dips are variable. As no stratigraphic significance is attached to the foliation no attempt has been made to work out structure. In any event more determinations of dip and strike would be needed than are now available.

Series 2. The crystalline limestones form a small area in the southern portion of the township. They are coarsely crystalline, graphitic marble, with much quartz disseminated through them. They are conformable with the strike and dip of the inclosing

[a] Similar rocks were studied by H. P. Cushing in 1897 and 1898 near Loonlake where they are regarded as belonging to series 3, and this is also quite possible in this area.

Plate 1

Geological map of Putnam township, Washington co.

gneisses. The familiar green aggregate of quartz and pyroxene that so often accompanies the exposures in Essex co. is present.

Series 3. The dark, basic gabbros appear at several points on the Lake George shore in the southwestern corner of the town. They have not escaped dynamic metamorphism, being now all more or less foliated but the gabbroic character is still recognizable. They consist of granulated labradorite, augite, hypersthene, hornblende, magnetite and garnet. In two places a different type of igneous rock has been found that probably should be placed in this series. It must have been originally a thoroughly crystalline porphyritic rock, with large phenocrysts of plagioclase, up to one inch across, and was probably a porphyritic diorite. At both exposures it has however been compressed and sheared so that it is now an augen-gneiss. The phenocrysts and groundsmars are thoroughly granulated and much biotite, presumably secondary has been formed. In no. 4 garnet rims surround the phenocrysts, appearing only along their outer edges. The mass of the rock impresses one as a coarse sandy aggregate, although the grains are now firmly bound together. Similar rocks to these were earlier met in Ticonderoga, and are referred to on p. 454, of the *Report of the state geologist, 1893.*

Series 4. Some extremely interesting outcrops of the paleozoic sediments appear in Putnam. The Potsdam is the most extensive of these and covers three or four square miles. Only a thin cross-section is however seen resting on the underlying gneiss. The beds are quartzites, which are often quite coarse conglomerates. In the southern area, near specimen 32, the conglomerate contains quartz boulders up to 6 inches in diameter. In the finer varieties ripple-marks are at times well developed. The quartzite is often very feldspathic and is practically arkose. The clastic material has been derived from the neighboring gneisses. The Calciferous is the usual, blue siliceous variety, characteristic of the Champlain valley. Its contacts against the Potsdam were in each case along faults. The dip of both is in all cases flat and nw or n.

Series 5. No trap dikes were found.

Series 6. Glacial drift is widely distributed over the interior valleys, but no special sign or color is used for it. Along Lake Champlain, the Champlain clays form a fringe that sets up into the depressions and that sometimes fronts the cliffs. Two sharply marked terraces are visible in the clays, one about 40 feet above the lake, (140 A. T.) and one 60 feet (160 A. T.). Still higher shore-lines are probably present,[a] but we made no special attempt to trace them. No fossils were noted in the clays.

Glacial striae were recorded in several places. In each instance the direction was northeast and southwest.

Mines, etc. There are no mines or other economic developments in the town.

Faults. There has been considerable post-Ordovician faulting. The sections AA and BB on plate 1, show these and bring out clearly the faulted contacts of the paleozoics on both the old crystallines and on each other. The faults trend in a north or northeast direction but the amount of the throw could not be determined. The Potsdam of the northern area reaches an altitude of 634 feet A. T., and the Calciferous, south of Putnam village stands about as high.

Dresden

Topography. Dresden presents much the same topography as Putnam. The high, rocky neck between Lake Champlain and Lake George is continued to the south, with a tendency to widen somewhat. The greatest altitudes, as before, are near Lake George. Mt Erebus in the southwest corner of Dresden, reaches 2533 feet and Black mountain 2665 feet, but there is no longer the gradual slope to Lake Champlain. On the contrary a steep rampart of fairly high hills fronts the latter. There are several east and west passes, of which the one running west from Dresden Center is the most notable. The valley of Pike brook is a marked depression with a bearing west of north, but aside from it, most of the brooks run nearly east or west into the two lakes. On the

[a] S. Prentiss Baldwin. Pleistocene history of the Champlain valley, Amer. geol. Mar. 1894, p. 170.

Plate 2

GEOLOGICAL MAP OF DRESDEN TOWNSHIP, WASHINGTON CO.

southeast Dresden borders on South bay, which really is the natural southern end of Lake Champlain. In the cliffs along the east front of Mt Diameter a most impressive and precipitous fault-scarp is presented, and indeed the shores of South bay constitute one of the most striking and instructive areas in the Adirondacks. Dresden is very sparsely settled and is mostly wild, mountainous woodland, which has been long since cut over by the lumbermen.

Series 1. The greater part of the town consists of this series as presented in the maps accompanying this report, but the rock of the larger part of the area departs from the typical gneisses as will be shown. All the metamorphic rocks show evidence of most intense compression. The foliation is fine yet persistent and though the individual laminae may be but a sixteenth of an inch thick, they run with great regularity. In the northern part of the town, from specimen 38 north, the gneisses are granitic in mineralogy, and contain many small garnets. Quartz is frequent and biotite is richly developed. Squeezed pegmatites may be detected. Again on the shores of South bay and along Pike brook, where the latter forms a cascade near its outlet, the gneiss is strongly and regularly foliated and makes the impression upon the observer of being derived from an original quartzite.

In the central part of the town, north and south of Dresden Center, the gneisses are green and of marked eruptive aspect. The foliation, although always discernible varies in distinctness. The feldspar of the rock has a bright glistening luster on cleavage faces and large porphyritic crystals are often noticeable. Some of these are striated and are plagioclase, but the major part are unstriated orthoclase. Thin sections show the same relative amounts of the two and with them are monoclinic and orthorhombic pyroxene and quartz. The pyroxenes under dynamic stress are largely altered to granular garnet. The orthoclase is chiefly microperthitic. This is the same rock that is mentioned under Putnam as forming the southern prolongation of Mt Defiance, and is a variety of the "Whitehall" type. It is really an augite syenite, but is a peculiar variety. It may be a member of the

intrusives constituting series 3, because in the northern Adirondacks, as noted by Cushing it occurs associated with the anorthosites. The present exposure is, however, not visibly connected with eruptives of the gabbro family.

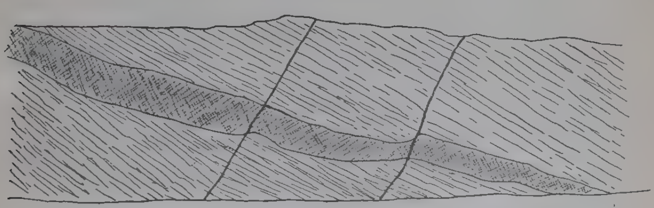
The strike of the foliation of the gneisses, is in large part across the trend of the topography, as is indicated by the signs on the map. East and west strikes are common, but northerly ones are not lacking. The dips are so irregular that much crumpling is shown, but very detailed work will be necessary to work out the structure, although the variability of the strikes and dips and their lack of connection with the topographic features leads to the conclusion that the latter are primarily due to faulting, irrespective of rock-structure.

Series 2. The crystalline limestones were met at only two localities one of which lies a short distance west of Dresden Center and the other is on South bay. The former exposure is small and is inclosed in gneiss as shown in section CC, plate 2. The limestone is much mashed and crumpled and is richly charged with pyroxene, pyrite and phlogopite. Along the highway just to the northwest of South bay, another small exposure was met. At the outlet of Long pond, pyritous rocks were found along the highway that resembled the usual associates of the crystalline limestone but none of the latter was seen.

Series 3. Six exposures of basic gabbros were noted in all, and several dikes in addition that probably belong with them. At the head of South bay gabbro appears in the foot of Mt Diameter. Again it is found along the highway a mile and a half to the northeast of the last. Two miles further another exposure is seen at no. 70. Just north of Dresden Station is a large intrusion, no. 10 and 21, and to the southeast at 37 is another. In the northwest corner are two, one at 18 on the mainland, and one, 103 on Odell island in Lake George. All these are dark, basic rocks, which exhibit as a rule the effects of intense compression. They form irregular intrusions and dikes in the gneiss.

On the northwest side of South bay is a dike of gabbro that is not indicated on the map except by the number 56. It lies at a quite flat angle with a northeast strike and a northwest dip. It cuts the foliation of the gneisses at a low angle as shown in fig. 1. The gneisses strike east and west and dip 30 N. Where the exposure is seen in a steep bluff along the shore, the shoreline runs northeast. The dike is broken and thrown a foot or two by a normal fault which is diagrammatically shown in the cliffs. Another plane of dislocation likewise crosses the dike but with an almost imperceptible throw. The faults strike northwest and dip southwest. The dike is 10 feet thick. The rock is excessively granulated, all the minerals except the feldspar being crushed to fine fragments as is shown in fig. B, of plate 5, which is inserted under Whitehall. The feldspars have suffered less granulation but they have not entirely escaped.

Fig. 1



Section of gabbro dike, spec. 56, on South bay, Dresden.

A short distance southwest another dark band was noted in the gneisses, apparently parallel to their foliation.

Precambrian quartzite. In Dresden and Whitehall townships the writers have met rocks which were considered by them in the field to be metamorphosed clastics and probably although gneisses now, to have been originally quartzites. It was remarked above that gneisses of this character were present at the Cascade of Pike brook, where the foliation, if indeed it be not bedding is remarkably perfect. Over the divide from the headwaters of Pike brook, and about a mile and a half southwest of Dresden Center, Mr Newland recorded a black quartzite on a

trip made alone by him, while the writer was working in Whitehall. The specimen 81, was lost in packing and the determination has therefore not been verified by the microscope, but on the strength of the field-notes the area is given a special sign. Still rocks were gathered in Whitehall, in the conviction in the field that they were quartzites, which microscopic study leads us to think are dynamically crushed eruptives and the determination above recorded for no. 81 is made with reservations. It is, however, impossible to visit the locality again before submitting this report. The writers appreciate that in this southeastern corner of the Adirondack crystallines they are approaching the metamorphic areas of northwestern Massachusetts and southern Vermont, and that in this portion homotaxial rocks might be anticipated if anywhere. But none have been yet definitely observed which enable us to trace any parallelism.

Series 4. Both the Potsdam sandstone and the Calciferous limestone are represented by very small exposures. The Potsdam was found in two small outliers well up within the hills. The more northerly lies about a mile and a half west of Snody dock. The sandstone is found on a steep hillside resting upon gneisses, and is only a foot or two thick and a few square feet in area. The locality is just below the outlet of Long pond, and on the roadside between the house and barn of a farm that is situated at this point. The strike is N 20 E, and the dip 10 E. The sandstone is ripple-marked and the ripples bear N 20 W. The waves that made the ripples on this sandy bottom must have come either from a direction south of west or from one north of east. This sandstone is now on the 900 foot contour and is one of the most elevated exposures of the Potsdam that we have observed.

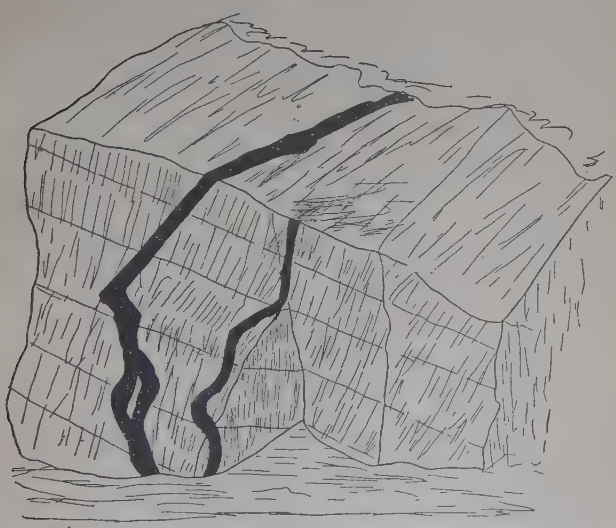
The small area in the Pike brook valley is larger and the beds are seen in several places, but they are of no great thickness. The strike is slightly different from the last, being N 10 W with a dip of 15 E. The ripple marks bear N. and S. In the sections EE and FF of map, plate 2, the bedding as drawn in the con-

ventional sign does not correspond to the dip. C. D. Walcott had previously noted this exposure.[a]

The Calciferous limestone forms a small faulted block on the Champlain shore about two miles north of Chubbs Dock. A specimen was also gathered at 23, in the extreme northeast corner, but it was not certainly in place. No higher members of the Ordovician appear.

Series 5. Trap dikes have been noted in three instances; one near 71, west of Snody dock, and a second on the shore of South bay near 88. The former appears to be disconnected with any larger eruptive mass and to be a diabasic trap of the common type. The latter may be an offshoot of the neighboring gabbro. There are also two narrow dikes of black igneous rock near 56, in a cliff on South bay, one of which appears to be an offshoot of

Fig. 2



Sketch of trap dikes on northwestern shore of South bay, Dresden.

the other although the connection is not visible. Fig. 2 illustrates their relations. The dikes stand vertically and cut the foliation at nearly a right angle. The large one is about 18 inches thick. A short distance further a nearly horizontal band of light,

[a] American journal of science. Ap. 1888, plate 3.

quartzose rock about one foot thick and resembling a sheet of sheared, quartz-porphyry, cuts the foliation of the gneisses and extends for about 100 yards. It is an extremely persistent sheet and is illustrated for a portion of its extent by fig. 3. There is little question that it was originally a pegmatite dike that is now sheared and pinched in with the gneisses. The minerals present are chiefly quartz, orthoclase and tourmaline.

Fig. 3

Sheared dike, supposed to be pegmatite, on northwestern shore, South bay, Dresden.

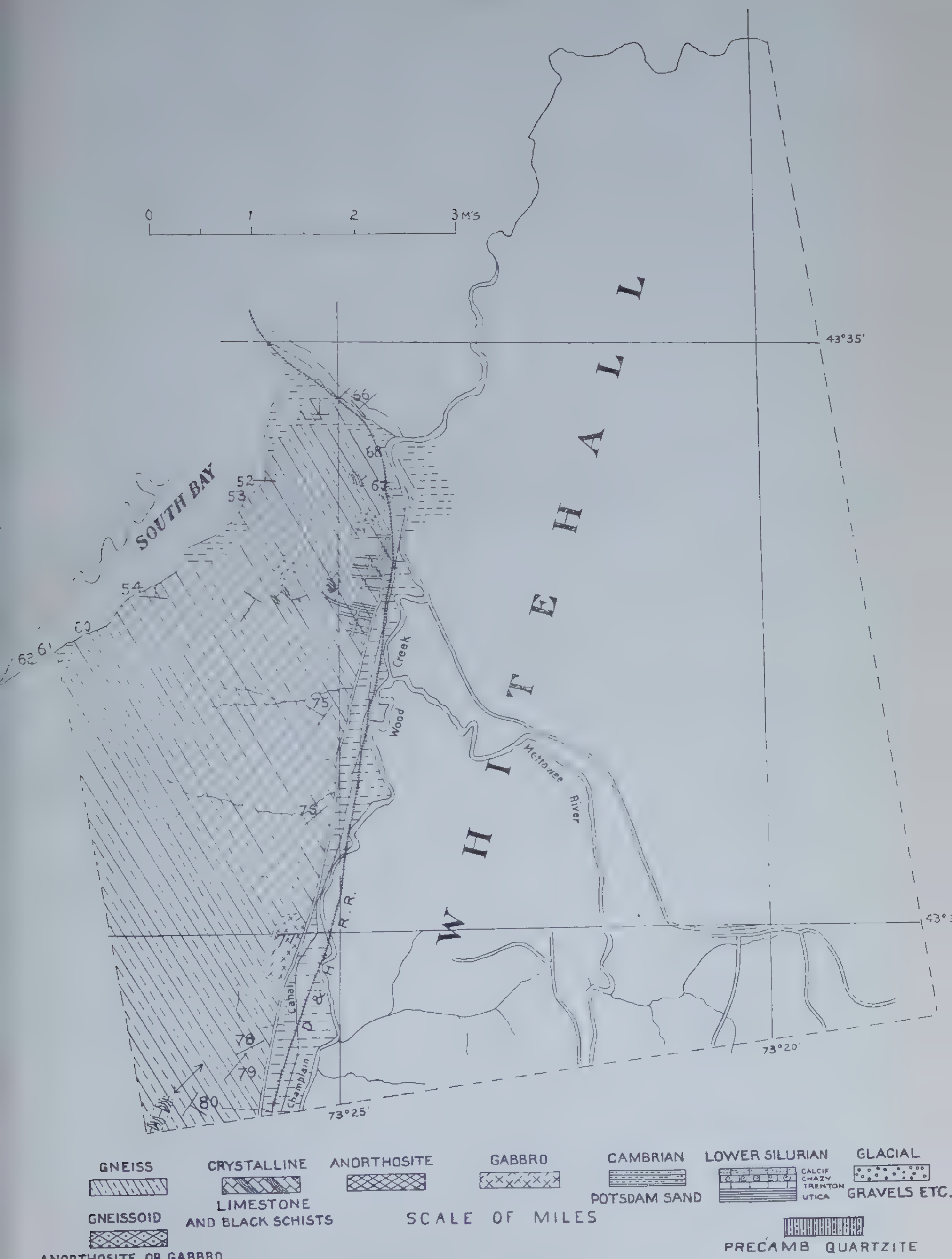
Series 6. The glacial drift is wide spread over the town. It may be assumed to be generally present in the depressions. Recognizable striae were noted just south of Snody dock, with a bearing N 60 E. While the grooving is in the same general direction as those noted in Putnam, the ice had swung around more to the southwest in its advance at this point.

The Champlain clays fill all the embayments and fringe the rocky ridges along the Lake Champlain front. They form terraces similar to those noted in Putnam. No fossils were observed in them.

Whitehall

Topography. Whitehall contains two parts much contrasted in topography and geology. The western third of the town consists of the crystalline rocks, which form the eastern half of a high ridge, lying between Wood creek and the Mettawee river, the inlets of Lake Champlain, on the east; and the southern prolongation of South bay on the west. The latter is a deep valley, and forms a striking topographical feature whose development is involved in the early drainage relations. It only concerns Whitehall in the portion filled by the South bay itself and in this the steep cliffs of Mt Diameter and the bluffs along the northwest front of Death rock give every reason for believ-

Plate 3



Geological map of Whitehall township, Washington co.

ing in the existence of a great fault line. The fault is probably continued in the depression filled by Lake Champlain, curving around to the northward, and while the latter depression has beyond question been a river valley in its later stages, as suggested by S. Prentiss Baldwin,[a] and as is apparent even to casual study of the topography from one of the neighboring hights, yet faulting is regarded by us as the prime cause that directed the original drainage.

The ridge of crystallines has a steep front to the northwest, precisely as does the ridge that forms the back bone of Dresden and Putnam townships, but the former ridge lies southwest of the latter, and the separation is due to the South bay fault, which is parallel in a general way with the depression of Lake George. There is great reason, we think, for believing Lake George to lie on another great line of faulting, with a drop on the northwest side.

The ridge in Whitehall slopes quite gradually to the east and southeast, and its surface is in general parallel to the dip of the foliation, so that it presents an outline that is often met in the Adirondacks. Certain other structural features will be later brought out, the purpose at this point being to specially emphasize the topography.

East of the ridge of crystalline rocks lies a valley, flat and filled with Champlain clay, and with streams at a base level. On the east side of the lines of drainage, except for two small hillocks along the inlet, below the town, all the rocks are of the Cambrian paleozoics, embracing on the extreme east the Georgian, and in the center several of the Ordovician members.[b] The paleozoic formation presents a very broken and hilly topography, partly from faulted blocks, like Skeen mountain, near Whitehall, partly from the greater relative erosion of softer strata.

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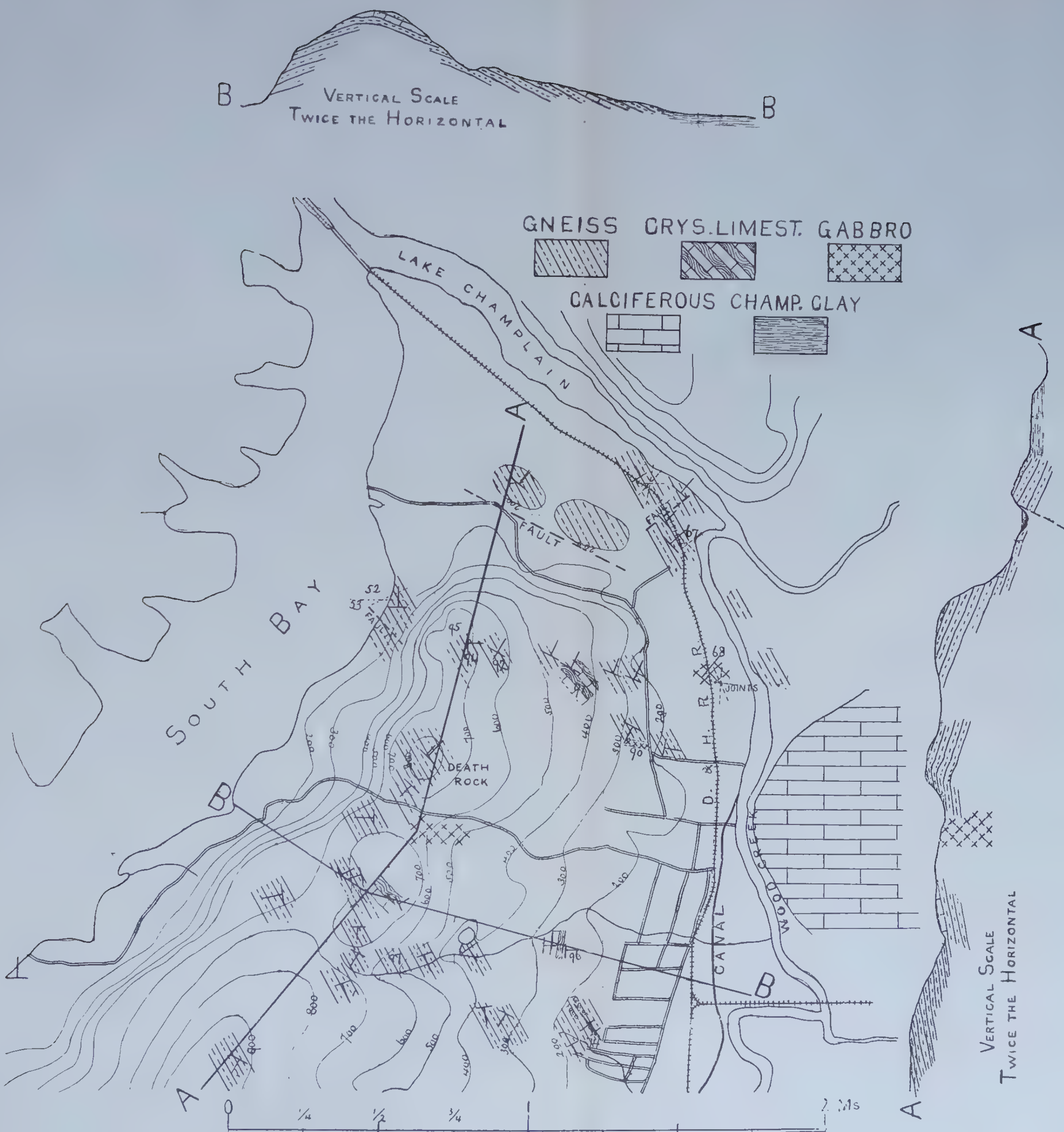
a Pleistocene history of the Champlain valley. American geologist, Mar. 1894, p. 170. Judge Baldwin treats specially of the Pleistocene times, but states, p. 171, "Lake Champlain occupies a long and narrow valley, probably only partly a valley of erosion, between the Green mountains on the east and the Adirondacks on the west." And again, p. 177, "While the uplifting of the mountains of Vermont and New York probably had much to do with the existence of a valley here, yet the valley itself is certainly a valley of erosion."

b C. D. Walcott. Map in Amer. journal of science. Ap. 1888.

Series 1. The gneisses are the chief representatives among the crystallines. They present not a few examples that resemble quartzites so closely as to lead us to believe in the extended development of the latter while we were in the field. More careful study in the laboratory with thin sections has in some cases thrown doubt over this interpretation, and it seems more probable that some at least are squeezed and granulated eruptives, but the question is not yet fully decided. Along the east side of South bay at 52 and 53, the gneisses resemble most closely sheared porphyritic types. The rock is strongly gneissoid and broken by innumerable cross-fractures with noticeable displacement. It is dark blackish green in general color, with lighter green augen or phenocrysts. The matrix is largely biotite, with some feldspar. The augen are flattened lenses of green feldspar that may be more than an inch across. Chips prove it to be microcline when examined under the microscope and lead one to infer that the original rock was a rather basic syenite porphyry, presumably belonging with other syenitic gneisses, in the outskirts of Whitehall. The latter occur along the eastern edge of the ridge that bounds the village on the west and have been quite extensively quarried at no. 74 on the enlarged map of the town, plate 4. The quarry is the locality for our "Whitehall type." They are finely and regularly laminated rocks that are green in color and that look extremely like a dark quartzite. They have lenticular augen of shining orthoclase, that has a brilliant luster. Rarely streaks of gray quartz run parallel to the foliation. Under the microscope they are found to be very finely granulated and to consist of small particles .1 mm in diameter (.004 in.). When examined with a high power these grains are found to be chiefly microperthitic orthoclase. Granules of green augite of about the same size are present and some magnetite can be detected. Zircons are rather noticeable and are charged with inclusions of still older minerals. There is little doubt that these rocks were originally the rocks often cited in the preceding townships and from Mt Defiance, and that they have been granulated by pressure. The layers seem to have slipped sometimes

Plate 4



Enlarged geological map of Whitehall village and the ridge to the west.

and to have developed biotite along the folia, but it is a minor component. Where shearing has been very pronounced a black shaly streak may be observed. This same rock occurs in some of the cuts along the D. & H. railroad just before it crosses South bay, and where faults cross the ledges the same black, crushed product appears. These exposures mark the southern extension of this type, as it runs out before the south line of Whitehall township is crossed.

Another gneiss is granitic in composition and is strongly contrasted with the variety just described. Instead of dark green it is light gray or almost white, depending on the amount of biotite that is present. The more biotite, the more pronounced are the dark folia, and the darker the shade. The feldspar is in marked lenticular masses yielding corresponding eyes or augen, and is also in general dissemination through the rock. Its excessive granulation has given it a milky white color when its amount is large, and when it is not stained with iron oxid. When it is more sparsely distributed through the leaflets of biotite is is gray. Cleavage surfaces of any marked size, say 5-10 mm (¼ in.) in diameter are rare, so complete is the granulation. Orthoclase is the commonest feldspar present and it may be microperthitic but commonly is not. Plagioclase is less abundant. Quartz is frequent and may be excessively rich as will be later brought out in several varieties. The dark silicate is biotite and its amount is variable. Garnets are practically omnipresent and at times are thickly strewn through the rock. They are a light pink and not so deeply colored as those in the basic rocks. Magnetite, apatite and zircon are sparingly present. There is little question that these gneisses have resulted from the excessive granulation and shearing of granites or from the metamorphism of a sediment related to arkose. The augen or eyes of feldspar would lead to the inference that the granites were porphyritic from large feldspars.

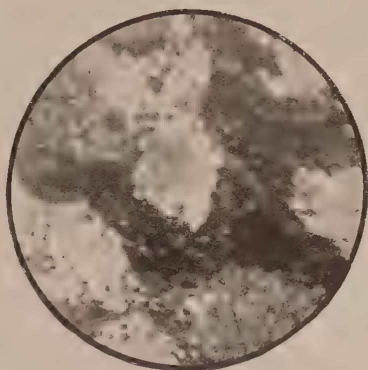
In two places, no. 54 and 60 on the east side of South bay, the feldspar has relatively diminished and the quartz has become prominent till the rock is almost entirely quartz, the " South Bay

type," some streaks of feldspar remain, and garnets are still quite thickly disseminated through the mass but about 80% of the slide on an estimate is quartz. The quartz is granulated and is strung out in bands. At no. 54 graphite is not infrequent in the rock, and appears as shining scales parallel with the foliation. Very small crystals of the manganese epidote, piedmontite are to be detected which are very pretty objects under the microscope. They seldom are more than .1 mm long by a fourth as broad. They yield the striking pleochroism of the mineral being green parallel with the elongation and blue or pink across it. The optical characters are those of piedmontite rather than thulite, the greatest axis of elasticity lying across the elongation, the least along it, as shown by the gypsum plate. A photomicrograph of this rock is given on plate 5, fig. A. It has garnets running in lenticular masses across the field and indicates the pinched condition of the rock.

In one of the railway cuts north of Whitehall and south of South bay specimen 67 was gathered and was regarded as a quartzite in the field. Under the microscope the same impression is difficult to avoid. The rock is a finely granular aggregate of quartz and looks very like a sediment. It is however in the midst of eruptives and it has been greatly crushed and compressed.

If both these rocks, 54 and 67, are not considered to be sediments they must be interpreted as pegmatites of such extreme richness in silica as to have been practically quartz veins. The pegmatites were then crushed and granulated. It is possible that an originally less siliceous rock has been enriched in silica after having been crushed, but if this is true, the process can not be readily if at all traced out, and demonstrated with the material in hand. The graphite strongly suggests a sedimentary origin, but it is not proof positive, because it is not lacking in the pegmatites of the region. The old graphite mines at Chilson hill in Ticonderoga are on pegmatite dikes or veins. On the whole, however, the writers are inclined to favor the sedimentary origin, and we hope to work out the stratigraphy more in detail in the future. Every outcrop should be mapped and the relations

A



B

PHOTOMICROGRAPHS. A, QUARTZITE FROM THE SHORES OF SOUTH BAY, WHITEHALL TOWNSHIP (SPEC. 54). THE DARK MINERAL IS GARNET, THE LIGHT, QUARTZ. B, GRANULATED GABBRO FROM DRESDEN (SPEC. 56). THE LIGHT MINERAL IS LABRADORITE, THE DARKER, AUGITE; THE VERY DARK ONE IS BROWN HORNBLENDE. ACTUAL SIZE OF EACH ORIGINAL, ⅛TH IN.

should be determined in this way. Somewhat similar rocks have been noted in other localities where there were crystalline limestones, and it is possible that the two may go together.

The granitic gneisses and their associated quartzose rocks form the chief part of the high ridge of crystallines and extend south into Fort Ann.

Series 2. The crystalline limestones have been found in four different places. Three lie at the north end of the metamorphic area and one in the extreme southwest corner of the town. There probably are others back on the ridge, which to the southwest has been but imperfectly traversed by us. The most northern exposure (*See* the special map of Whitehall village, spec. 91) is the thickest. It was estimated to be 300-400 feet across by Mr Newland, is charged with silicates and apparently conformably inclosed between the gneisses below and an overlying bed, supposed to be a quartzite. The exposure at 96 is a small one, and that on the crest of the ridge at the intersection of the two cross-sections is likewise thin. We can not state positively whether we have the last-named one located exactly right on the map, though it is not far from its true position. The minor hillocks on the summit of the ridge do not correspond with the contours as drawn on the Whitehall sheet, as the latter have been sketched from a distance and are general in their character. While a road is drawn as crossing the ridge, that might seem to be available as a point of departure in orienting oneself, yet the ridge is traversed by many wood-roads, quite as good as this one and both of the writers were much at a loss in plotting the geology. A thin stratum of white crystalline limestone does exist however, and is encompassed in metamorphic siliceous rocks. The stratum was about 6 feet thick and conformably included in the gneiss, so far as one could judge.

Series 3. Four exposures of gabbro have been met, all greatly compressed, gneissoid in structure and black in color. One outcrop appears in the railway cuts just north of Whitehall. The rock in thin section is a norite, with abundant hypersthene, now granulated by dynamic metamorphism (spec. 67). The gab-

bro at no. 90 (*see* large map of Whitehall) is a dike of which at least 50 feet are exposed across the foliation and the contact with the inclosing gneiss is visible and is irregular, though its general strike is east and west. The gabbro near the crest of the hill is similar in appearance to the others but its shape or other relations could not be determined. The large outcrop along the highway to the south is the most extensive of those found. The contact with the granitic gneisses which form the country rock on the south is well shown and is irregular, apparently as if offsetting tongues of gabbro had been pinched into the gneiss. The gabbro itself becomes very gneissoid.

Precambrian quartzite. In the closing paragraphs under the head of the gneisses the peculiar schistose rocks were described which simulate, if they actually do not represent quartzites. Should our impression that they are quartzites be corroborated by more detailed work, they would add an interesting and important member to the Precambrian strata.

Series 4. The paleozoics cover two thirds of the township. The lowest member is the Georgian slate of the lower Cambrian. The next formation present is the Potsdam sandstone of the upper Cambrian, which appears in the base of Skeen mountain. The Calciferous rests on it forming the top of the eminence and is also met elsewhere. Slates determined as Hudson by Mr Walcott form a broad belt east of the Calciferous, and are the latest paleozoic beds present. As already stated we have given almost no attention to the paleozoic exposures, inasmuch as they had been already mapped by Mr Walcott, whose results have been incorporated in the state geological map.

Series 5. Only one trap dike has been discovered. This occurs south of Whitehall at specimen 68. It is 6 feet wide, and strikes—N 65 E—being a fine example of its kind. It outcrops in a barnyard.

Series 6. Glacial drift is not infrequent on the ridge. In only one place in the extreme southwest corner were striae discovered of a measurable distinctness. These bore N 40 E, and are shown on the map by the double-pointed arrow.

The Champlain clays are much the most prominent of the pleistocene deposits. They fill the valleys and fringe the hills and while most pronounced between the lake level and the 140 foot contour, they have been found in small areas as high as the 400 foot contour, on the hillside west of the town, if the locality is rightly located on the topographic map. Due west of Whitehall and just south of the line of section BB of the enlarged map, plate 4, is a small pond between the 380 and 400 foot contours. Clay occurs along a wood-road still higher than this pond, and a short distance west. This altitude is above any given in Mr Baldwin's paper earlier cited, and while we had no barometer with us, there seemed no doubt about the identity of the pond. The one visited by us was an abandoned mill-pond with a broken and dilapidated dam.

Structural geology. The hill west of Whitehall affords us one of the few places where we have been able to work out a satisfactory solution of the structural relations. It is a doming anticline. The foliation is so pronounced and definite that dips and strikes can be taken with the same facility as in sediments. Beginning on the north with section AA of plate 4, we find a low northerly dip in the two faulted blocks, which project from the plain of Champlain clays that surround them on all sides. Crossing the fault and passing up the large hill, the same conditions hold for about a mile, and then the dips with some minor rolls, turn to the southward and still with low inclination from the south portion of the fold. Passing now along section BB, we find that an anticline is also present from east to west, and of a somewhat more pronounced character. The two sections together indicate that there is a pronounced fold with a north and south axis, which is further bent by a cross-fold with an axis approximately east and west. If we use Pumpelly's law that the minor crumplings have an axial direction parallel to the large ones, the direction of the latter may be inferred from the axis of a small fold that was well shown at 74 in the quarry in the outskirts of the southern town. Its axis bears N 40 W. On the mountain the dips are so gentle that a great number of

observations would be necessary to establish the exact alignment. Though greatly attracted by the problem, we felt unable to give longer time to it than sufficed to prove the larger features. Not a few cross-gulches on the summit of the ridge suggest the presence of cross-faults. There is also crumpling at the north end of the hill near the summit but its axial bearing from imperfect outcrops we did not ascertain.

Faults. Faults of diagrammatic perfection are displayed at two points in cliffs. In the cut on the railway just north of the post, 79 miles from Albany and 112 from Rouse Point, as shown on the enlarged map of Whitehall (plate 4), a fault has mashed the green gneiss to a band of dark, shaly, fault-breccia. The line of displacement trends N 45 E, and is parallel to a pronounced system of joints, along which a throw is not discernable in most cases. Two or three minor faults also appear in the same cut.

The finest fault met by us, is however to be seen on the east shore of South bay, at no. 53. The fissure strikes in a direction N 45 W, and is nearly vertical. It has produced a zone of crushed, rusty, kaolinized, fault-breccia 6 to 8 feet wide that from a distance looks like a porphyry dike. The soft rock has been eroded so as to form a little recess in the cliff and as it visibly runs up for 30 or 40 feet it affords a most beautiful illustration of this phenomenon. There are apparently other small breaks and brecciated joints along the same cliff.

If now we attempt to decipher the topography by means of the clues afforded by these two lines of disturbance, it is noticeable that the escarpments are chiefly parallel to them. For example, the cross-fault assumed to exist beneath the little valley at the north end of the main ridge bears in the same general direction as the fault at 53. The same is true of the escarpment, which will be found on the northeast side of Lake Champlain and which is known as Austin hill. The southwest escarpment of Skeen hill in Whitehall village also shows the same bearing, the hill itself being a faulted rectangular block with an escarpment parallel to each of these fault directions. The same characters hold good for other blocks outside the limits of our map.

The northeast fault line is parallel with South bay and the escarpments that face it, and with many others in the paleozoic area.

Fort Ann

Topography. Fort Ann is a very large township that lies between the head of Lake George and the valleys down which flow the inlets of Lake Champlain. Generally speaking it consists of three great ridges of gneiss, separated by intermediate valleys, and it has an additional projection to the southeast that runs out into the paleozoic area. The western ridge fronts on Lake George for six or seven miles and is the southern prolongation of the one described under Dresden. Its altitude gradually diminishes to the south however, for while Black mountain in Dresden is 2665, Sleeping Beauty in Fort Ann is 2349, Buck mountain 2334, Pilot Knob 2180, and finally in the southwest corner the hills scarcely top 500 feet. This great ridge is somewhat bolder toward Lake George than to the southeast, precisely as is the case in Dresden.

The inlet to South bay forks about a mile above the bay into two brooks. Mount Hope brook comes in from the southwest in a deep valley, at whose highest point is Lakes pond, at 859 feet A. T. On the other fork which comes in from the south the divide is not over 300 feet and is a moraine, as was first stated by G. F. Wright.[a] On the other side of the moraine the drainage runs to the south into Halfway creek.

The southerly flowing streams in both these valleys just referred to, turn a sharp corner and come back in a direction north of east through Halfway creek into Wood creek and so into Lake Champlain at Whitehall. All the relations lead to the inference that there has been a reversal of the drainage and that the discharge formerly went southward into the Hudson, possibly through the channel detected by Prof. Wright[b] at South Corinth. The subject demands, however, more detailed study for its elucidation than anyone has yet given it.

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a Science, Nov. 22, 1895, p. 676.

b Science, Nov. 22, 1895, p. 675.

The two valleys just referred to are separated by a high ridge of gneiss, known as Putnam mountain, which, like its associates, is steep to the west and of more gradual slope to the east. On the east again and lying between the southern prolongation of South bay and of Wood creek is Pinnacle mountain, the extension of the ridge of crystallines just described in Whitehall. It also has a steep westerly front and a gradually sloping easterly one. A deep valley, however, on its eastern side divides it into two ridges. In the valley is Pinnacle pond—a small one, that does not appear on the current editions of the Fort Ann sheet of the U. S. geological survey. This may be a valley due in part to the erosion of crystalline limestone.

The southeastern corner of Fort Ann consists of paleozoic strata in minor hillocks, which give a very picturesque and diversified topography.

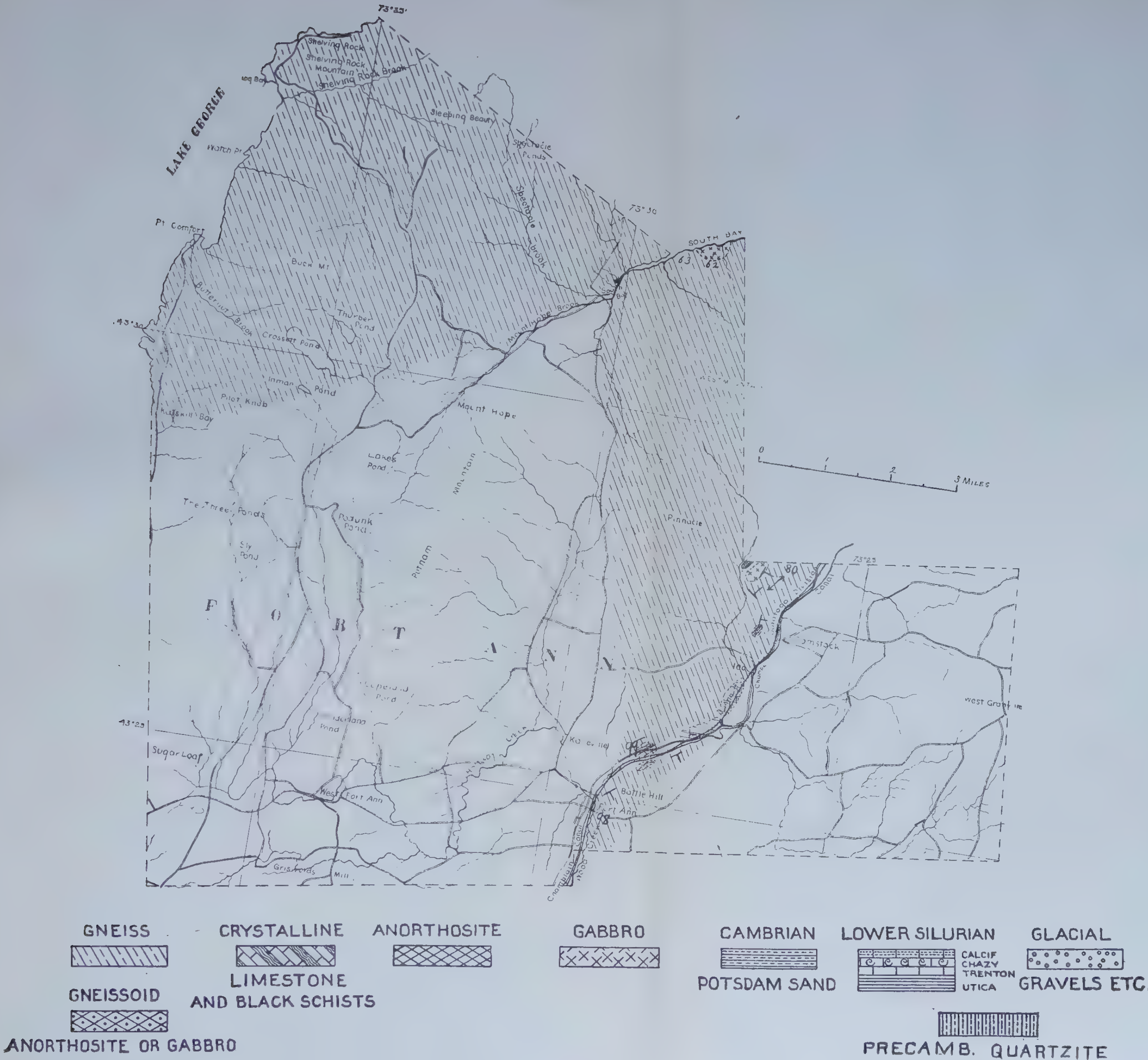
Our field work in 1897 did not cover all of Fort Ann, but was limited to the ridge between Wood creek and the South bay extension, and to the northwest corner along Lake George.[a]

Series 1. The gneisses cover much the larger portion of Fort Ann, and exhibit the same types which have been met in the townships to the north. The paleozoics encroach on them on the southeast and in the valley which sets up from Fort Ann toward South bay. On the shores of South bay, within the limits of Fort Ann, the gneiss is a richly quartzose, garnetiferous variety (the South Bay type), like the one described under Whitehall from neighboring parts of the ridge. It consists of lenses of quartz up to an inch (25 mm) or more in length and $\frac{1}{8}$ inch (3-4 mm) in thickness. Garnets to one quarter inch (6-8 mm) are distributed through the mass. Feldspathic matter is a subordinate component. The outcrop of this rock proves so extensive that we are again strongly inclined to consider it of sedimentary origin, as was stated under Whitehall.

In the southern end of Pinnacle[a] mountain the gneisses are finely laminated garnetiferous varieties of general granitic min-

[a] In 1898 the remaining part was mapped. It is chiefly gneiss, of the same general characters as are outlined above.

[b] The Pinnacle hill, Fort Ann, is not to be confused with "The Pinnacle," in Granville.



Geological map of Fort Ann township, Washington co.

eralogy. No. 80 contains lenses or eyes (augen) of orthoclase, with reddish biotite and some quartz. No. 100 closely resembles a quartzite. It is a garnetiferous quartzy rock with a little biotite and feldspar. No. 98 is a thinly foliated feldspathic gneiss of granitic composition, but almost a schist in structure. Quartz is fairly abundant.

Series 2. The crystalline limestones appear in several small outcrops in the southeastern crystalline areas. They are of moderate thickness, sometimes less than 10 feet, and in one instance, at no. 98, about 100 feet. The limestones are thickly charged with pyroxene and graphite, and show the effects of mashing and shearing. At 98 one of us (Mr Newland) detected an apparent unconformity at the eastern edge of the limestone and between it and the gneiss. The gneiss dips southeast, the limestone northwest, although both strike N 40 E. Apparently there is brecciation at the contact, due to faulting. General phenomena of this character were observed by Pumpelly, Walcott and Van Hise in 1890[a], and a cut of one of the limestone ledges in this region is given in the 16*th annual report of the director of the U. S. geological survey*, part 1, p. 772, pl. 113. It brings out forcibly the way in which masses of gneiss have been torn off and involved in the limestone in the general mashing. These included fragments of gneiss, it is fair to state, have been interpreted by Pumpelly[b] as the products of ancient superficial decay, which became involved in the limestone sediment during the invasion of the ancient sea, but the writers can not support the suggestion.

Series 3. Gabbro occurs on the shores of South bay in a large intrusion that runs at least 200 feet along the shore. The bordering gneisses are much contorted, and at the western edge the gabbro is apparently finely crystallized next the contact. A small intrusion likewise occurs near the southwest corner of Whitehall township.[c]

Series 4. The paleozoics fringe the crystallines to the southeast, both the Potsdam and the Calciferous being met. Two

a See U. S. geological survey. Bulletin 86, p. 398.

b Bulletin geol. soc. of America, 1892, 2:218.

c In 1898, two other areas were met just northwest of Copeland pond by B. F. Hill, and a third about half a mile south of Podunk pond.

small Potsdam areas are shown on the map to lie on the west side of Wood creek, between Fort Ann and Comstock. The paleozoics also extend up the depression in which lies Halfway creek and its tributary from the South bay valley, Calciferous being the member present.

Series 5. No trap dikes were met.

Series 6. The glacial deposits are widespread and of great interest, but beyond a few notes we have not been able to give them important study, as they require close and detailed work. The moraine that lies south of South bay and that has been already referred to has been a serious factor in developing the drainage relations, as already noted in the introductory remarks on this town. The Champlain clays lie in the valley of Wood creek, and water-sorted sands are widespread in the southern part of the town. Glacial striae were observed near specimen 80, which bear N 40 E. The problems of the pleistocene history of this section must be largely solved in Fort Ann township, and the beginning has already been made by Messrs Baldwin and G. F. Wright.

WARREN CO.

Warren co. is roughly rectangular in shape with an additional projection to the south on the southeast corner. It lies to the west of Lake George, and fronts the lake for two thirds its entire western boundary. The line is continued a little east of south from Warner Bay. Lake George itself lies entirely in Warren co. except for a small portion at its northern end. The boundary of Warren as against Washington co. is the eastern shore line of the lake. In general topography the county consists of a series of northerly and southerly ridges, with an easterly trend more often than a westerly and with several marked depressions. Brant lake lies in one, Schroon lake and the Schroon river in another, Loon lake and Friends lake with their connecting stream in another. The valley of the Hudson cuts diagonally across the county from northwest to southeast. In the western part of the county the depressions are chiefly those of the East Branch of the Sacondaga river (flowing southwest) and its tributaries; Thir-

teenth lake and its outlet, draining northeast to the Hudson, and Stony creek, flowing southwest to the Sacondaga. The Sacondaga river describes a very peculiar course for after the junction of its two branches, one from the northeast and the other from the northwest, it turns back in the edge of Fulton co. and takes a northeast course across Saratoga co. into the Hudson at Hadley. This is so striking that on the map it suggests a reversal of the drainage.

The towns will be taken up in the following order so far as the field work for 1897 affected them. In 1898 the gaps were largely filled up. Bolton, Chester, Hague, Horicon, Thurman, Stonycreek, Hadley, Day and Luzerne.

Bolton

Topography. Bolton lies along the west shore of Lake George, about midway of the lake, and it consists chiefly of one large and one smaller ridge, between Lake George and the valley of the Schroon river. The smaller ridge is cut off from the main one by Northwest bay and its inlet, the brook of the same name. It is known in general as Tongue mountain, and its northern peak, Fivemile mountain, is the highest part of the township, 2258 feet. There is little doubt that it is a faulted block. It is somewhat steeper towards the lake, or to the southeast, which is the reverse of the usual relation but it may be caused by a normal fault with a dip to the east, whereas in previous cases the faults dipped west. The main ridge, forming the body of the township, consists of a rather broad aggregate of minor elevations, of which the highest is scant 2000 feet and the general run is about 1500. Indian brook lies in a valley of moderate size, and Trout lake marks another depression with a north and south axis.

Series 1. Our collections from Bolton are not as complete as could be desired but our observations embrace in the way of reconnaissance all but the extreme southern limit of the town. The commonest form of gneiss is that derived from the dark green augite-syenites which were described quite fully under Whitehall and were called the Whitehall type. They consist of

orthoclase in largest part, the same being often though not always microperthitic. Plagioclase of an acidic variety is not lacking but it is far inferior to orthoclase. The dark silicates are emerald green augite, hypersthene, brown hornblende, and considerable garnet, which in all probability has been derived from the bisilicates. Magnetite is in moderate amount and may furnish the core of a garnet aggregate. Apatite is often noticeable in small crystals. The rocks have been greatly granulated and sheared by dynamic processes and may yield excessively fine gneisses with thin but persistent laminae. On the slipping surfaces much biotite of a golden brown has developed. Quartz is variable but some of the specimens gathered yield it in considerable quantity.

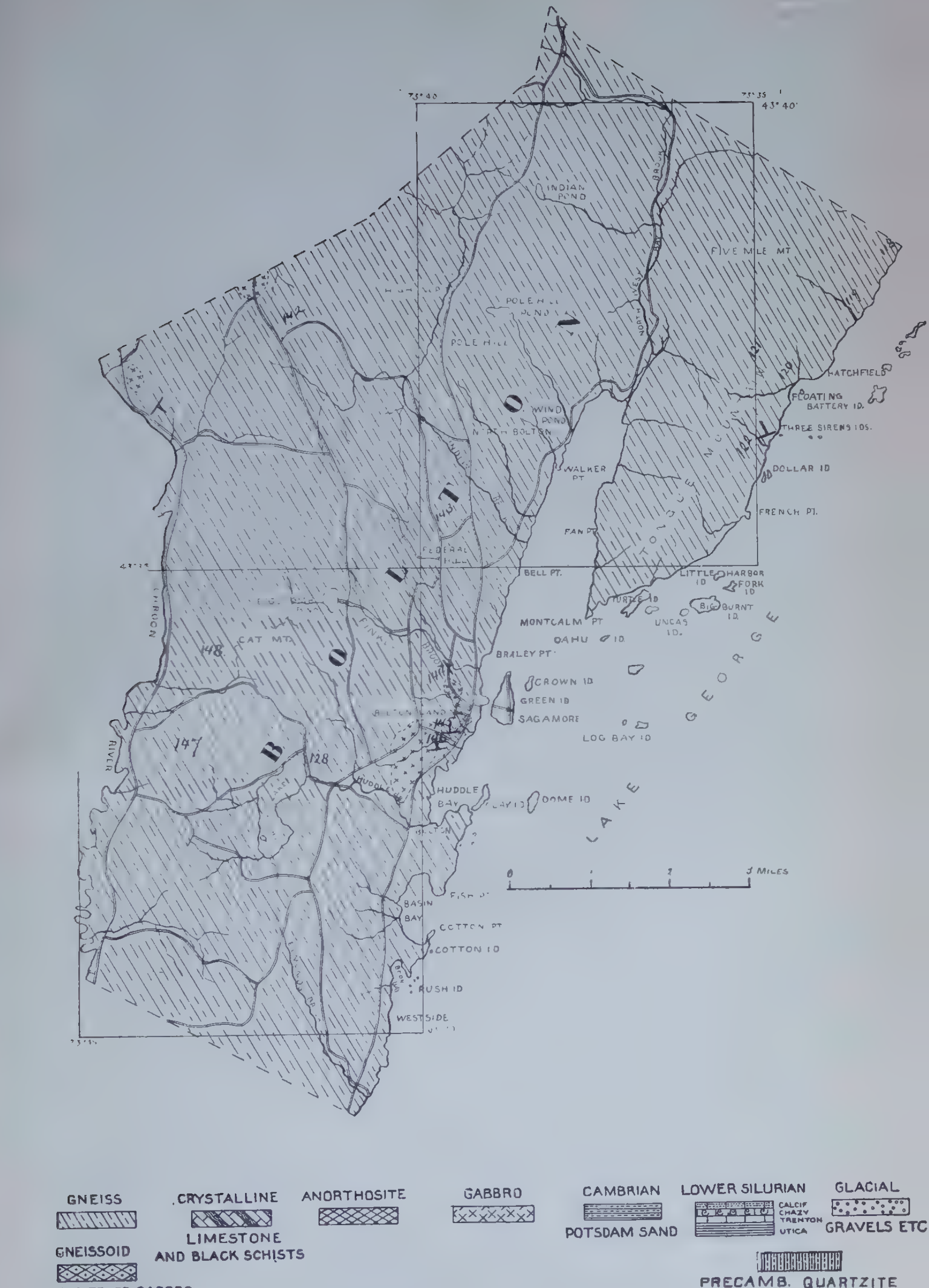
These syenite-gneisses of the Whitehall type make up the eastern front of Tongue mountain and presumably the western slope as well. Our specimens 119-22 inclusive were gathered along the eastern slope. The same variety was also collected along the highways leading northwest from Bolton Landing to Brantlake.

On the northern of the two roads which run from the lower (north) end of Trout lake and near the Schroon river a white, granular rock with larger quartz crystals through its mass was met at 147. In thin section this contains orthoclase of microperthitic habit in considerable abundance together with quartz, microcline and oligoclase. A stray garnet occasionally appears. The rock is thoroughly granulated and has evidently been subjected to great strain and thorough crushing.

At 148 however on the western slope of Cat mountain the syenite-gneiss again appeared.

Just northeast of Trout lake a coarse granulated syenite porphyry was collected, which exhibits the results of pressure and mashing in a marked degree. It has a coarse groundmass of greenish orthoclase and biotite, with a little plagioclase, and large red lenticular phenocrysts of microcline, which are now chiefly granular aggregates. This recalls the similar rocks cited under Whitehall, and is like no. 128 from a quarry north of Horicon village.

Plate 7



GEOLOGICAL MAP OF BOLTON TOWNSHIP, WARREN CO.

Series 2. In the village of Bolton Landing a belt of white crystalline limestone is met, and associated with it are quartzose, micaceous gneisses and pegmatites with graphite, such as are usually found in the vicinity of this member. One dense green rock, that is excessively rusty on exposed surfaces, exhibits under the microscope garnet, quartz or scapolite, (the grains are so fine that it is difficult to discriminate) pyrrhotite, apparently rusted biotite and either graphite or magnetite. This type is not infrequent in the vicinity of the limestones and betrays itself by its proneness to rust.

Series 3. Dark, basic gabbros were observed in five places in all. The largest is just south of the village of Bolton Landing. Another lies just north, while three others were in the extreme northwest.

Series 4. We have met no paleozoic exposures.

Series 5. We have met no trap dikes.

Series 6. The glacial deposits are widespread over the town. The post-glacial terraces on the Hudson are of special interest. Two well developed ones were noted along the western central border of the town, respectively 25 and 45 feet above the river. This would be about the 720 and 740 foot contours. We have not however studied these phenomena with sufficient care to justify extended mention of them.

Chester

Topography. Chester lies between the valleys of the Schroon lake and river on the east, and the valley of the Hudson on the west. In its southern, central portion it contains two rather large lakes, Loon and Friends. Over most of the township the the elevations are moderate and picturesque affording a diversified topography, without any specially marked trend. The greatest elevations are just along the northern border. Green hill on the northeast reaches 2227 and Maxham mountain on the northwest 2461. The western divides of the feeders of Loon lake and Friends lake are close to the Hudson, though these lakes discharge into the Schroon. This appears to be due to the

gradual easterly slope of the hills, and to their steep westerly fronts, the same relation noted around Lake Champlain. Apparently the Hudson in this part of its course, follows along a fault line whose western half has dropped.

Series 1. The prevailing gneisses in Chester are coarsely laminated, biotitic varieties, with feldspar as a rule in considerable excess and with abundant garnets. They exhibit many evidences of mashing and the micaceous streaks forcibly suggest slipping surfaces. More basic varieties with abundant, or it may be, predominant hornblende have been noted in a few places, and they seem to constitute subordinate streaks in the gneiss.

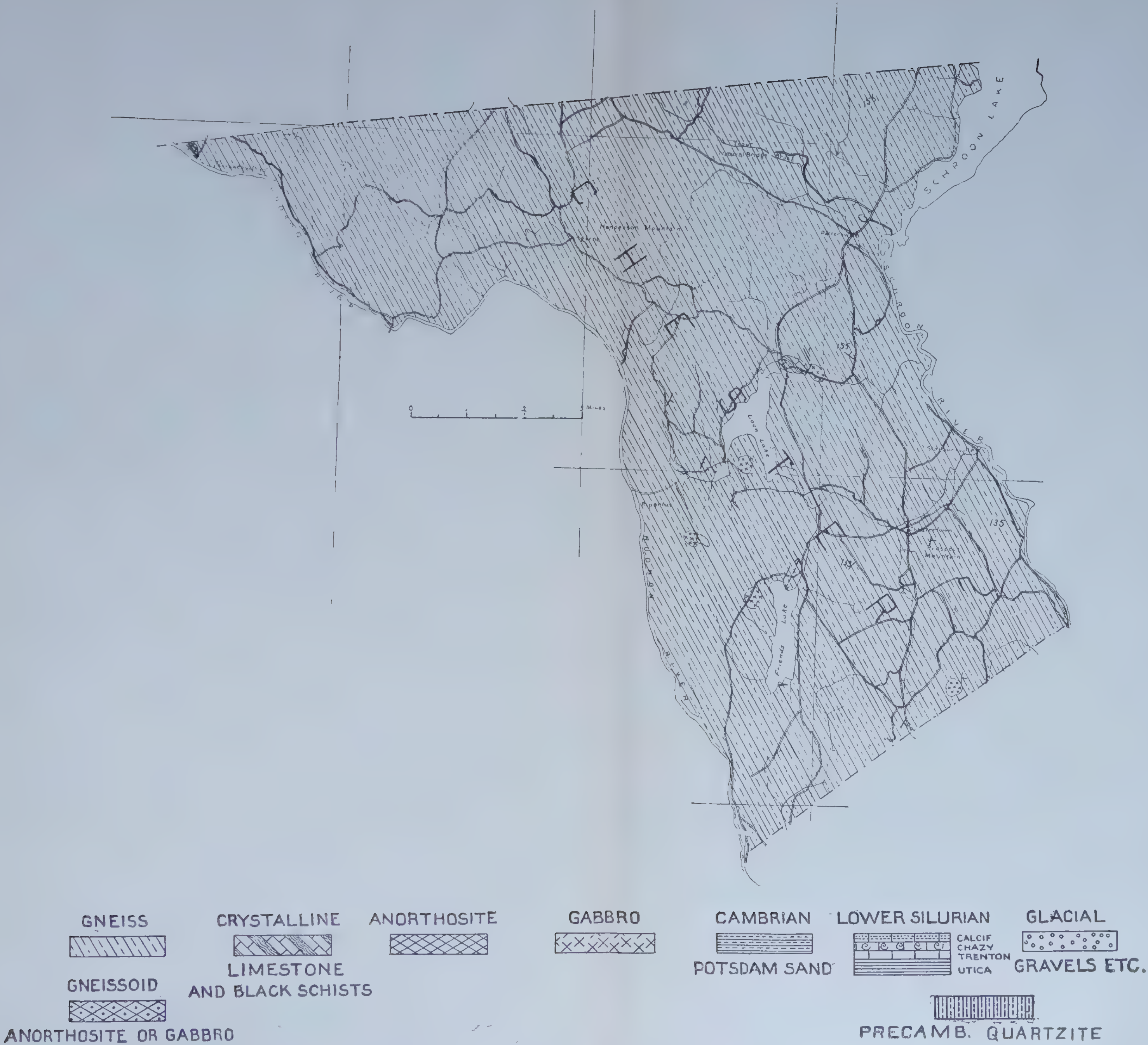
At a point about midway between the north end of Loon lake and the Schroon river, a stratum of dark gray quartz about 20 feet thick was found interbedded in the gneiss, and having sharp contacts with it. Many little flecks of pyrites are distributed through the bed, and some mica and garnets. We regard it as a thoroughly recrystallized quartzite. The clastic character has been destroyed and the rock now gives the impression of vein quartz.

Pegmatite dikes have been noted in one or two places, and in one instance a dike was the basis of an unsuccessful mining venture for mica. The dike is near a gabbro intrusion on a hilltop about three miles south and a little east of Chestertown.

Series 2. The crystalline limestones outcrop at two points, one at the northern end of Loon lake, just east of the outlet and one at the extreme northwest corner of the township opposite North river. The former is charged with pyroxene, graphite and quartz, and the latter is very thickly set with pyroxene, but both appear to be interbedded in the gneisses. The latter will be again referred to under Minerva.

Series 3. Three exposures of gabbro have been met in the central part of the town, near the two lakes, Friends and Loon. The one just west of Friends lake, is associated with pegmatites containing tourmaline. The one southwest of Loon lake in a coarse variety, with lath-shaped feldspars which have the pyroxenes of irregular outline packed in between them, after the manner

Plate 8



Geological map of Chester township, Warren co.

of a diabase. Quite large bits of magnetite are present, and though no thin section has been made, apparently hypersthene is one of the components. The gabbro shows a tendency to pass into amphibolites along the margins.

Series 4. No paleozoics occur in the township except Potsdam boulders, which may be occasionally observed in the drift.

Series 5. No trap dikes were met.

Series 6. Glacial deposits are widespread and post-glacial or supposed post-glacial sands are frequent. Chestertown is situated in a broad valley with abundant drift. Pottersville is partly built upon a terrace, that stands about 40 feet above the Schroon river, which would make it about 850 feet A T.

Hague

Topography. Hague is the northeastern township of the county and on the east lies along Lake George throughout its entire extent. It is quite a mountainous area, whose highest summits exceed 2000 feet. As a great rampart on the north Stevens mountain reaches 2153, Third Brother 1956 and Trumbull mountain 2220. The southeastern portion is occupied by Catamount mountain 2304, and its spurs. The valley of Fly brook divides the town into two east and west portions, in the southern two-thirds, and then the east and west depression marked by the brooks entering Lake George at Hague, and Mill brook flowing west into Brant lake, cuts off the northern third. Trout brook, which crosses the northeastern corner and enters Lake George at Ticonderoga presents some striking reversals of direction in its upper tributaries and leads one to suspect stream piracy. The surface of Hague rises steeply from Lake George and at Rogers Slide in the extreme northeast and at Deer Leap on the southeast precipitous escarpments front the lake.

Series 1. The gneisses constitute much the greater part of the township and they embrace several varieties of rock. There is a granitic type that may be quite massive. It is rich in quartz, has mostly feldspar for the remainder and comparatively few dark silicates. Specimen 103 B from the cliff called Deer Leap is of this character. On Agnes island a variety richer in dark

silicates is met but still a quite acid rock (spec. 102A), no. 115 near Sabbathday Point, and no. 117 at Davis bay are similar; no. 115 is a fairly massive binary granite.

At Sabbathday Point a somewhat sheared dark porphyritic rock is met, similar to varieties collected in several localities in Essex co. It consists in fresh specimens of a dark green groundmass of augite which is emerald green in thin section. In this aggregate are set large greenish crystals of plagioclase, now kaolinized. There is much apatite and much titanite also present. If shearing effects this rock the feldspars become lenticular and the dark silicate is drawn out into marked foliation. No. 109 west of Sabbathday Point on Bloomer mountain is the same rock.

A third type of gneiss is the green rock which was specially described at Whitehall and which has been called the Whitehall type. It has been already often referred to as augite-syenite gneiss. Hague contains both very basic and very acidic varieties. The augite-syenite yields on pressure a dark green gneiss, with variable amounts of feldspar and augite. It is found at Deer Leap, south of Sabbathday Point, specimen 103 A; at no. 110 due west of Sabbathday Point; at no. 116 on Vicar's island; and abundantly on Tongue mountain in Bolton. It is also in great amount in the southwestern portion of the township and along the southern border. As already stated we have gathered in former years a great deal of it in Ticonderoga just across the border to the north. Our observations are however somewhat fragmentary in the inaccessible parts of Hague on the southwest and northwest, and we feel conservative about making sweeping statements regarding them. Along the road from Graphite to Brantlake the rock was noted beyond Swede pond.

A fourth type of gneiss results from foliation induced as nearly as we can tell on a porphyritic granite of the kind quarried near Horicon village, no. 128. This was gathered at no. 114 back of Hague village, and is the "Horicon type."

The strike of the gneisses wherever determined has been almost without exception, northwest. The dip about Sabbathday Point is northeast, near Hague village it is southwest.

Plate 9

GEOLOGICAL MAP OF HAGUE TOWNSHIP, WARREN CO.

Series 2. We have secured record of the white crystalline limestone at only two points. One is at the steamer dock at Sabbathday Point, where at low water it is stated, limestone is exposed. The other is in a deep boring at the new prospect at Graphite, where Mr Frank Hooper informed us that limestone was penetrated 30 feet below the surface. The limestones also occur at Rogers Rock, but whether in Hague or Ticonderoga or both we can not say.

In Hague township there are however the most interesting metamorphosed sediments of Precambrian age that have yet been met in the eastern mountains. The principal outcrop and the one best exposed is at the graphite mine about four miles west of Hague village, but other rocks which are with little doubt altered sediments are met at several other points in the town. The graphite deposit will be first taken up and then the others. The graphitic deposit is an impregnation or dissemination of graphite in quartzite. The graphite forms leafy masses among the grains of quartz and seemed to lie along slipping surfaces which have rubbed them out into small striae. Beyond question there has been movement in the rocks of a most pronounced character and they have been squeezed and mashed with a sliding along the bedding. The quartz contains a good many small apatites and probably zircons and rarely shreds of biotite, but in the large way there is little else than quartz and graphite present. This simplifies the problem of concentrating the graphite, with which any scaly mineral would interfere. The foot and hanging walls are a tough, dense, green, garnetiferous gneiss, a peculiar rock that has not been noted elsewhere. Large red garnets up to half an inch in diameter are buried in the greenish, fibrous matrix. In appearance the rock suggests somewhat the eclogites of Bavaria, but in thin section the hanging wall is found to be almost entirely sillimanite and garnet (*see* plate 10, fig. A and B). There is a little quartz and more or less graphite, and some small accessories, but other minerals are lacking. The sillimanite forms fibrous aggregates with roughly parallel alignment and of size from very fine rods up to prisms $\frac{1}{25}$ of an inch (1 mm) in diameter. It is broken by the cross frac-

tures common in this mineral. Its optical properties are normal. Thin sections across the foliation of the rock give basal sections of the sillimanite and excellent biaxial interference figures.

The foot wall has more quartz and contains also microperthite. Otherwise it is like the hanging.

The oldest rock of all is a hornblendic gneiss on which the others rest. It has the general mineralogy of a granite, with some variations. It contains quartz, microcline, microperthite, brown hornblende, emerald green augite, magnetite and titanite, and is a type not infrequently met. It probably belongs in the general eruptive series with the Whitehall augite-syenite gneiss. It may have preceded the sediments but that is not yet demonstrated. At all events it occurs below them.

Above the sillimanite-gneiss lies a quartzite without graphite, and the same variety of rock is met just west of Hague village and at several points along the road from Hague to the mines.

The graphitic quartzite and its wall-rocks are repeated by faulting as shown on the map and section, fig. 4.

Series 4. The paleozoic rocks occur at but one point and that is between Silver bay and Van Buren bay. A drab limestone is found which appears to be Calciferous.

Series 5. No trap dikes were found.

Series 6. Glacial drift is widespread. Striae are occasionally discernible. Just north of Sabbathday Point they range N 25 E. A mile west of Swede pond they run N 35 E. Clay sets up the valley of Northwest brook, and reaches the town line of Hague although mostly in Bolton.

Economic geology. The graphite mine is the only development of the useful minerals of the township. It is mined, crushed and stamped in a battery of California stamps and then buddled so as to save the lighter portion, while the heavier quartz is eliminated in the tailings. When concentrated to about 50% graphite, it is taken to Ticonderoga and washed up to a product that is suitable for lubricants, but the process is kept secret.[a]

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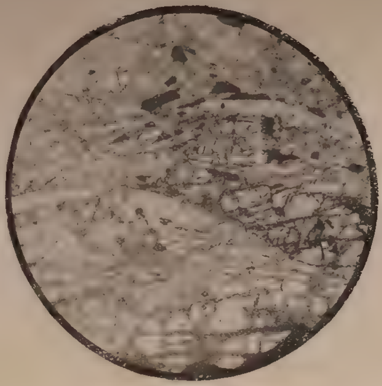
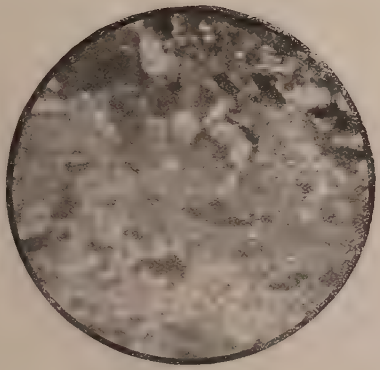
[a] The graphite mine in Hague has received mention once or twice already in print. C. D. Walcott, in the bulletin of the U. S. Geological survey, no. 86, p. 391, describes it in a single sentence as follows: "A graphite mine in the neighborhood of Hague is a layer of very graphitic gneiss, comparable to a coal seam in an ordinary bedded succession." See further note with a photoengraving of one of the open cuts, Bull. geol. soc. Amer. 10:227, pl. 22. An anonymous writer in the Engineering and mining journal, Aug. 24, 1889, p. 158, under the head of "Vacation notes on northern New York," also refers to it.

Plate 10



A



B

PHOTOMICROGRAPHS OF SILLIMANITE-GARNET-GNEISS FORMING THE WALL-ROCK OF THE GRAPHITIC QUARTZITE THAT IS MINED AT HAGUE. A, SECTION PARALLEL TO THE FOLIATION AND SHOWING LONGITUDINAL SECTIONS OF SILLIMANITE IN THE LONG RODS. AT THE BOTTOM AND THE RIGHT ARE LENTICULAR CRYSTALS OF GARNET WITH DARK EDGES AND CRACKS. A LITTLE GRAPHITE SHOWS IN BLACK. B, SECTION ACROSS THE SILLIMANITE RODS SHOWING AT THE BOTTOM AND ON THE RIGHT THIN SQUARE CROSSSECTIONS. THE DARK MINERAL IS GRAPHITE. ACTUAL SIZE ⅛TH IN.

Horicon

Topography. Horicon is a large township, which lies along the eastern side of Schroon lake and Schroon river, and extends eastward so as to include Brant lake, a large body of water, in its southern, central part. It is bounded on the east by Hague, no topographic feature marking the border. Horicon is hilly and diversified with few elevations of notable hight. It is provided with a great number of small ponds.

Series 1. The gneisses in Horicon are of a granitic mineralogy in most cases. They are strongly laminated and contain much biotite. The prevailing feldspar is apparently orthoclase or microcline, but they have not been determined by the microscope and the statement depends on their similarity to other known forms. Just north of the village of Horicon is a hill on which is located a quarry that has given excellent exposures of the country rock. The latter is now a coarsely prophyritic variety whose large pink feldspars 1-2 in. (or 25-50 mm across) are pretty thoroughly granulated microline. The groundmass is a mixture of brown and green biotite, quartz, greenish orthoclase and plagioclase, thoroughly granulated into particles $\frac{1}{8}$ inch (3 mm) and less in diameter. Zircons, apatite, magnetite and pyrite are also present. The rock lacks gneissoid foliation to a great degree in the quarry, but it assumes it strongly on the north face of the hill. This exposure is of the highest significance, because it gives us the clue to the derivation of some thoroughly gneissoid and even schistose varieties from a massive granite porphyry. Somewhat similar porphyries have been already recognized in Ticonderoga, Bolton and Whitehall, in addition to Horicon, and their schistose derivations when once the passage is established so that the varieties can be recognized, will be found we are confident in many places. An important step results in solving these metamorphic problems. The specimens on which the above statements are based are no. 128 and 129. At 130 near Round pond the gneiss is a sheared granite and is finely laminated; 138 is similar from a point a mile east. At 140 a little further southeast a greenish rock like the Whitehall type of syenite-gneiss,

which has been so often referred to, was gathered. It contains however, abundant quartz, and is an acidic member of this series.

The same type of rock is found to the east, extending into Bolton. Somewhere about no. 132 a fault breccia was met which has innumerable angular fragments of gneiss, mixed up in a black groundmass or paste of chloritic decomposition products. The remaining gneisses of the township are quartz, granitic in their mineralogy, i. e., they contain quartz, orthoclase, biotite, plagioclase, and sometimes hornblende. They are often thickly seamed with pegmatite dikes, specially in the neighborhood of the crystalline limestones. The western shores of Brant lake, near the outlet, are illustrations, though at this point no limestones have been found.

Series 2. The limestones appear in six different areas which will be at once apparent from the map. They are of the usual variety, coarsely crystalline, white marble, thickly set with pyroxene crystals, and often provided with graphite and with pegmatite streaks. They appear to be interfoliated with the gneisses, but we have not been able to discover evidence of other sedimentaries with them. The gneisses do however often assume schistose structures near them, more often than elsewhere.

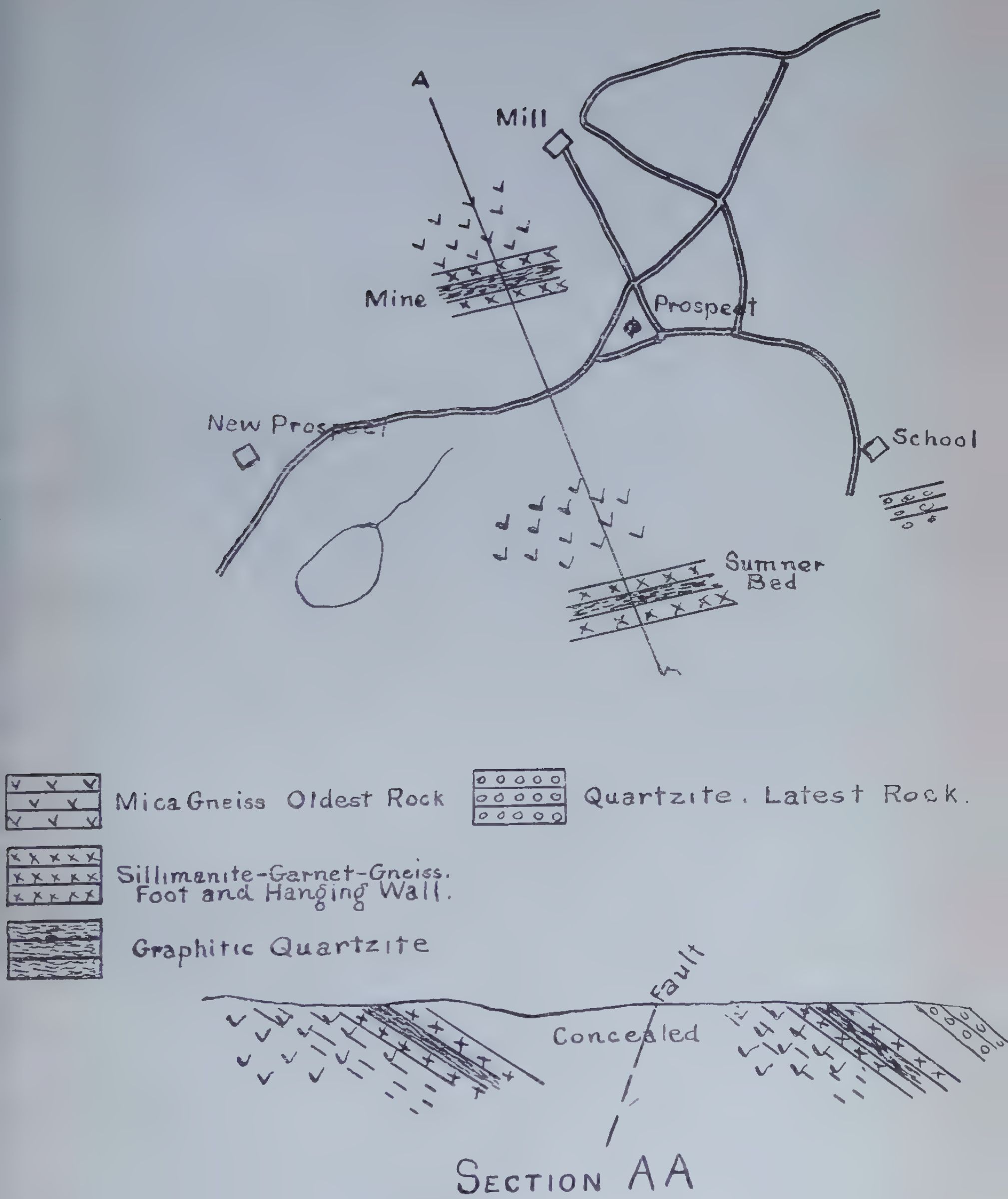
Series 3. In the southern part of the township, gabbros are quite abundant, eight exposures having been found in all. They are of the usual variety, and are not infrequently squeezed to hornblende schist. At specimen 139, about a mile east of Burnt pond, a gabbro dike has been shattered by faulting and pressure and into the cracks granulated gneiss like the country rock has been squeezed so as to form a matrix in which the masses of gabbro are set. The gabbro has resisted granulation much better than the gneiss, and has broken into angular fragments several inches across, while the gneiss has granulated and flowed.

Series 4. The township contains no paleozoic strata. Boulders of Potsdam sandstone occur in the drift.

Series 5. No trap dikes were observed.

Series 6. Glacial drift is frequent and widespread. Striations or scratches have been observed in three instances. One south

Fig 4



Map and section at the graphite mine, four miles west of Hague

of Beaver pond bore N 10 E; another about a mile southeast of the lower end of Brant lake was N 15 E, and the third near Burnt pond was N 10 E. They coincide with other observations in the region.

Abandoned lake bottoms, now meadows or swamps have been noted in several instances in the valleys.

Economic. The quarry near Horicon is said to have furnished some stone for the state capitol, and its dark groundmass with mottlings of pink feldspar ought to afford an attractive stone. A well has been drilled to a depth it is said of over 2000 feet through the gneisses in the extreme northwest corner of the town in the hope of finding petroleum. Some rumors have spread that traces of oil have been discovered but it is manifestly absurd to look for liquid or gaseous hydrocarbons in these old metamorphosed crystalline rocks.

Thurman

Thurman is a large township that extends from the valley of the Hudson, westward almost 20 miles to the Hamilton co. line. It contains several peaks of considerable altitude—Mt Blue for example reaching 2925—and between the ridges are deeply incised valleys.

In 1897 only the eastern portion was traversed so that a full report on the town can not be made with the data now in hand.

Series 1. The gneisses form the larger part of the eastern portion of the township and present much the same characters as those to the north and south. They are hornblendic, so far as one can determine them with the eye, but under the microscope they would doubtless show the usual green pyroxene and occasional hypersthene, with microperthite and more or less quartz, characteristic of the Whitehall type.

Series 2. The crystalline limestones and ophicalcites and their associated rocks are quite widely developed and have indeed received some attention as sources of ornamental stone.[a] The series projects into Thurman from Johnsburg and forms a con-

[a] G. P. Merrill Ophiolite of Thurman, Warren co. N. Y.—Amer. jour. sci., Mar. 1889, p. 189.

siderable area in the eastern central part of the town as shown on the map. Another small area lies about four miles east of Thurman station.

Series 3, 4 and 5 are lacking in the town so far as known to us from the 1897 work.

Series 6. Glacial drift is widespread and water-sorted material affords interesting terraces along the Hudson.

Stonycreek

Stonycreek is another large township that extends from the Hudson to the Hamilton co. line. Only its eastern portion was studied in 1897.

Series 1. The country rock so far as certainly found in place in the eastern part of this town is gneiss, except for one outcrop of gabbro. No. 202 from Bald mountain, is a rusty brown, coarsely crystalline variety, with lenses of quartz, drawn out with their long axes parallel and presenting a series of thin elongated projections on the weathered surfaces. The quartzes give the exposure a very rough exterior. This variety of gneiss has not been previously observed by us in the southern Adirondacks, but it is quite abundant in the northern along the line of Clinton and Franklin counties with Essex. Mention is made of it in the report for 1895, p. 582, where it is noted in northeastern Jay, Essex co. This latter specimen exhibited under the microscope, quartz, microperthitic orthoclase and microcline, hornblende and a little biotite. Prof. Cushing also discovered large quantities of it in Franklin Falls township, Franklin co. where it outcrops as a rusty, quartzose gneiss. On the south side of Stonycreek stream, about two miles below Harrisburg, no. 204 was collected. It is the green, syenitic variety of gneiss, often referred to above as the Whitehall type. The same variety is present to the south.

Series 2. But one outcrop of crystalline limestone was noted in 1897. It is about two miles southeast of Stonycreek postoffice, on the road to the railway station. The exposure was a poor one and may have been a boulder.

Plate 11

GEOLOGICAL MAP OF HORICON TOWNSHIP. WARREN CO.

Series 3. One outcrop of the usual dark gabbro was discovered. It was found at the bridge over the creek on the road from Stonycreek Station to Stony Creek Center (or postoffice), specimen 203. It is the usual gabbro.

Series 4 and 5 were not found. Of Series 6, the glacial drift is widespread and terraces along the creeks are sometimes striking. On Stony Creek, two or three miles below Harrisburg, three may be observed, for whose correlation with others, topographic maps will be needed. No glacial scratches were noted.

Hadley

Hadley is a comparatively small township, that lies along the west bank of the Hudson at the southern boundary of the county. The Sacondaga river enters the Hudson from the west, dividing the southern third from the northern two thirds of the town.

Series 1. All the ledges that were noted in Hadley are gneiss. No. 205, from the area north of the Sacondaga, is a well-foliated feldspathic representative of the Whitehall type. It contains microperthitic orthoclase, plagioclase, deep brown hornblende, and considerable quartz. Garnets are visible to the eye, and extensive granulation has been caused by pressure. No. 217, from the extreme south is a very finely foliated variety, and one that has been so excessively crushed as to resemble a compact quartzite. In thin section some plagioclase and some orthoclase are present, and more or less biotite, but the chief mineral is quartz.

Series 2, 3, 4 and 5 were not observed.

Of series 6 the glacial drift is widespread and is often watersorted. The terraces so often observed in this county are beautifully developed. Along the Sacondaga river, between Conklingville and Hadley village, two respectively 30 and 60 feet above the river, are striking features of the local geology.

Attempts at gold-mining have been made upon the gravels along the Sacondaga about one and one half miles west of Hadley. A stamp-mill has been erected, but no disinterested assays of the gravel are available.

Day

Day lies west of Hadley, and, like it, is cut by the Sacondaga into two unequal parts. Only gneisses and glacial drift have been as yet noted. No. 208 is a coarsely foliated gneiss of the mineralogy of a biotite-granite so far as one can determine with the eye alone. Observations as yet relate only to the eastern part of the township and to the highway along the Sacondaga.

Luzerne

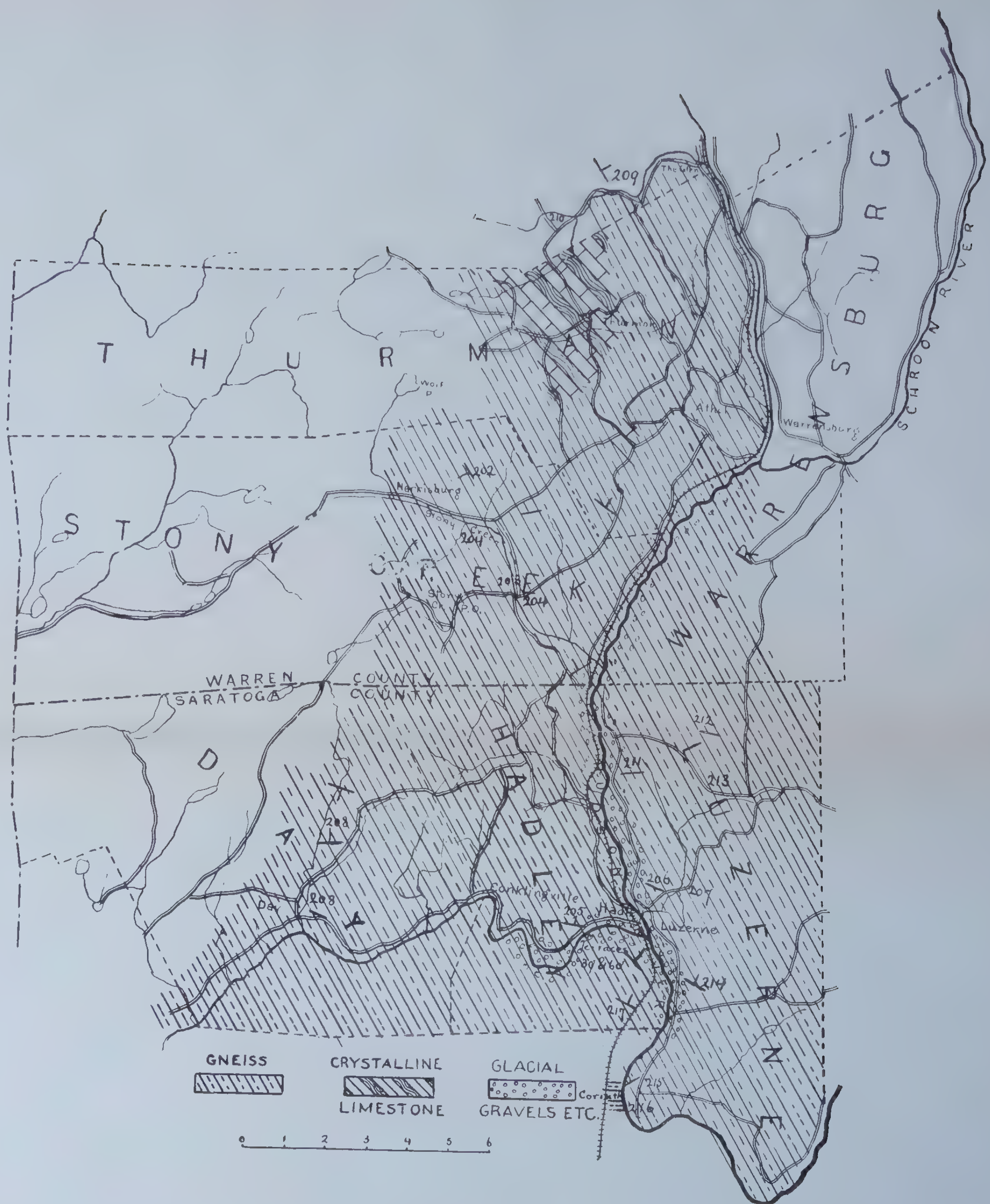
Luzerne lies along the east bank of the Hudson, opposite Hadley, but extending farther south. It is a narrow township in an east and west line, being but three to four miles across. The township contains, so far as we have observed, gneisses, paleozoic strata and glacial deposits.

Series 1. The gneisses cover all the town, except for a small outlier of the paleozoic sediments near Corinth. The gneisses are chiefly of the Whitehall type. They vary from quite massive and poorly foliated varities, like no. 212 and 207, to very finely foliated varieties, like 215. These rocks present in thin section quartz, microperthite, more or less plagioclase, brown hornblende and sometimes green augite. No. 215 is a deceptive rock, being light green in color, thinly foliated and resembling a crushed and gneissoid anorthosite. It is, however, an aggregate of finely granulated quartz, microperthite and plagioclase, with prominent lenses of quartz, which one can not help regarding as recemented granules, and which are together larger than any original quartz crystal. At 206 garnetiferous, biotite gneiss was recorded in the field.

The peculiar rounded knob, as viewed from the south, known as the Potash Kettle, is a most remarkable topographical form. It is a coarsely foliated gneiss, no. 212.

Series 4. A small northerly outlier of paleozoics is found in the Hudson valley near Corinth. The beds cover only a very small area and are a remnant of a former extension of the large southern exposure. The best exhibition of the beds is on the

Plate 12



Geological map of Thurman, Stonycreek, Day, Hadley and Luzerne townships, Warren co.

west bank of the river, and indeed it is not certain that any actually outcrop in Luzerne, but as systematic work has not yet been undertaken in Corinth our observations are recorded here.

The most northerly exposure is under the west end of the bridge over the Hudson at Corinth. About 24 feet of Potsdam are exposed. The lowest eight feet contains some slaty layers, the next eight feet is a dark gray, slightly calcareous quartzite, resembling limestone and having some shaly layers. The uppermost eight feet are quartzite. A hundred feet below the bridge there are six feet of conglomerate quartzite resting on gneiss and evidently a basal conglomerate. 500 feet below the bridge 50 to 60 feet of Potsdam, with a low northerly dip, are exposed. On the quartzite is sand of series 6 with boulders of gneiss. These exposures of Potsdam have been noted briefly by N. H. Darton.[a] The outlier of Calciferous at Schroon Lake postoffice about 40 miles farther north, gives some ground for thinking that paleozoics formerly extended much farther in this direction.[b]

No trap dikes of series 5 were found. The glacial drift is widespread, and interesting terraces were noted along the river. No striae were recorded.

ESSEX CO.

Minerva

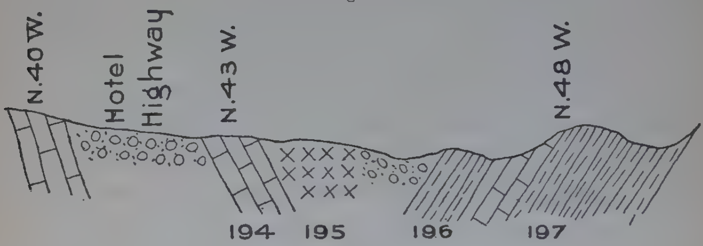
Some observations have been made in Minerva in order to fill out the gap left in the map that was issued in the report for 1895, p. 602, plate 9. As there given the northwestern corner of the town was not colored in. Mr Newland has been over parts of it and has visited the neighboring townships north and west. There is no question that the country rock is gneiss, but there may be crystalline limestone areas and outcrops of gabbro in it that we have not noted. The gneiss is the Whitehall type. It is prevailingly gray to greenish and contains quartz, microperthite, plagioclase, hypersthene, and often hornblende and green augite. Zircons and pyrrhotite are the chief accessory minerals. Granula-

a Report of the state geologist. 1893. p, 410.

b J. F. Kemp. Physiography of the eastern Adirondacks in the Cambrian and Ordovician periods. Bull. geol. soc. Amer. 8:408–12.

tion from dynamic processes is widespread. On the section, fig. 5, which was run a little north of east near Kellogg's hotel, Minerva postoffice, no. 196, resembles a sheared, red granite, but the

Fig 5



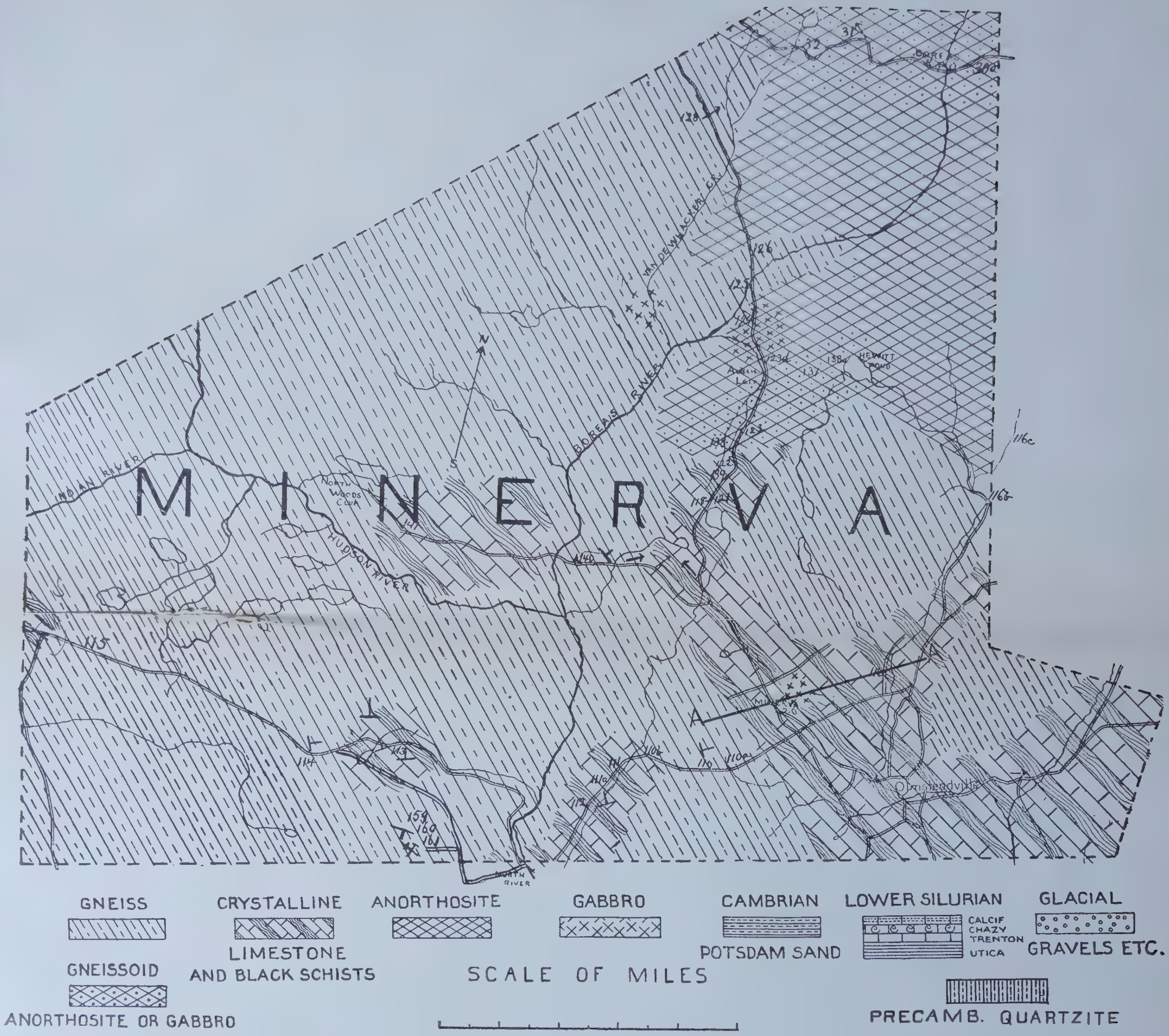
Section A A near Minerva Village.

mineralogy is doubtless that given above. There is evidence of a syncline at this point, with an intrusion of gabbro in the bottom of the trough. Specimen 197, is a peculiar green pyroxenic rock, containing quartz, and green diopside chiefly. It is a close associate of the limestone. Near the line of the section garnetiferous mica schist was also met, no. 198. An area of crystalline limestone not hitherto recorded was found at the extreme western edge of the town, where the highway to Blue Mountain lake passes.

Among the most interesting forms of rock in the township are those associated with the garnet mines in the southern part near North River. It was stated in the previous report[a] that these are in Warren co. This is a mistake. The mine now operated by the Messrs Hooper lies in Minerva, but very near the line. The brownish red, massive garnet lies in a hornblende schist or amphibolite, of which it forms about 15-20%. Crystal outlines are lacking, the mineral occurring in rounded masses up to 8 or 10 inches in diameter. It is much cracked and granulated. The rock containing it is chiefly coarse brown hornblende, with some basic plagioclase and some pyrite. Occasional pockets rich in feldspar are met. The garnets are more or less shattered and

[a] Report of N. Y. state geol. 1895. p. 604.

Plate 13



GEOLOGIC MAP OF MINERVA TOWNSHIP.

show signs of having been subjected to pressure but they exhibit no optical anomalies.

The wall rock of the garnetiferous bed is a gray or greenish gneissoid variety that consists of quartz, microperthite, plagioclase, rarer orthoclase, orthorhombic pyroxene, augite, zircon and pyrrhotite. The foliation and the garnet bed dip sharply to the south. A little over a mile to the north and on the other side of the Blue Mountain highway is found a second garnet bed high up in a steep escarpment north of the road. It dips to the northeast. Between the two lies a valley with limestone, apparently forming the eroded core of an anticline. There is reason to think that the two outcroppings of garnet rock belong to the same bed.

The garnet rock is mined at the southern exposure, crushed, washed and shipped in considerable amount each year, as the mineral is a highly prized abrasive. The origin of this peculiar bed presents an interesting theme. The country rock is probably igneous. Its mineralogy and structure favor this derivation. The garnet rock must be either an altered form of a very impure limestone, or else a very basic igneous rock, that was an original sheet or dike. The former supposition appeals more strongly to us.

Just to the south and east of the garnet mine and between it and North River, great quantities of huge boulders of Potsdam sandstone were noted in the fields. Fragments as much as 30 feet by 15 feet were found in so fresh and unweathered a condition that it was difficult to believe that they were not in place. It would seem as if there must have been in this valley an outlier of the Potsdam, similar to the others discovered elsewhere in the mountains, and that it has been but slightly broken up by the ice. No assured examples of the rock in place were, however, found. The boulders are on the north side of Thirteenth brook and mostly in Warren co.[a]

Across the Hudson from North River an interesting section is afforded of pyroxenic limestone next the river, striking N30

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[a] The Potsdam was found in place in 1890 by B. F. Hill.

W and dipping 30 NE. Over it after a concealed interval there is a coarse micaceous, quartzose gneiss, with nearly the same strike and dip viz N 35 W 40 NE. The latter contains narrow bands of hornblende schist.

Minerva is one of the richest townships in crystalline limestones of any and together with Newcomb, it would probably yield valuable stratigraphic results if mapped in detail.

Newcomb

A partial sketch of Newcomb was given in the *15th annual report New York state geologist*, p. 604. At the time that it was prepared, field work remained to be done in the northwestern and southwestern portions of the township. That has now been performed and a fairly complete outline of the town can be given.

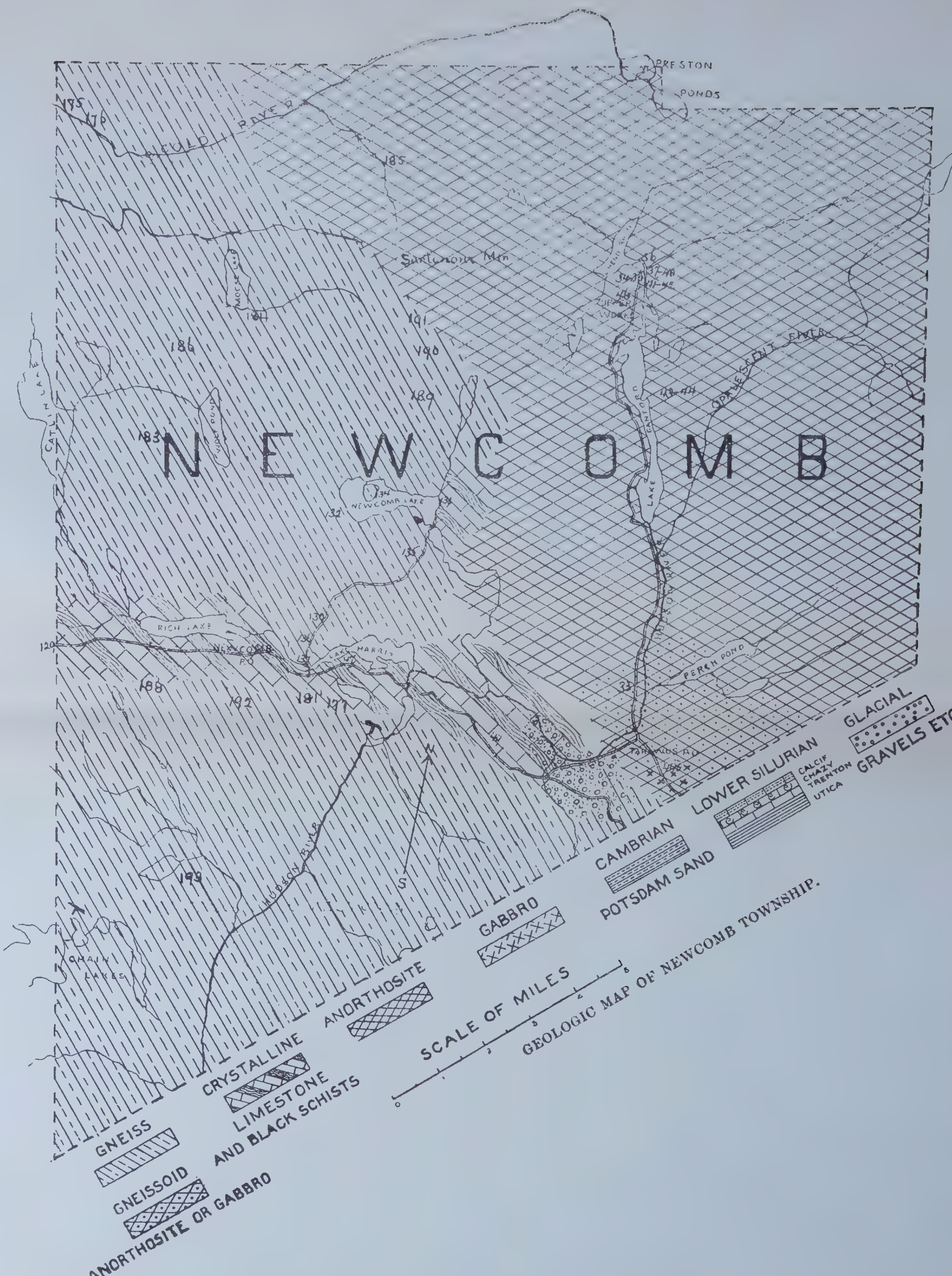
Series 1. The gneisses have been found to cover all the northwestern and southwestern portions of the township. They are greenish varieties, apparently of hornblendic character to the unaided eye and present in almost all cases the features of the syenitic rocks, often referred to as the Whitehall type. They vary from more acidic forms with free quartz, to quite basic varieties, with abundant dark silicates that simulate gabbros and that have troubled us greatly as to their identity in the field. Under the microscope these rocks are found to contain orthoclase, largely microperthitic, subordinate plagioclase, varying amounts of brown hornblende, emerald green augite, and hypersthene, sometimes one sometimes another predominating. They therefore are regarded as an eruptive rock, it may be of series 3 that has been foliated by dynamic metamorphism.

Near the areas of crystalline limestones, biotitic and more schistose varieties of gneiss are met, that are characteristic of this series.

Series 2. In the areas more recently traversed, no new limestone outcrops have been noted but there may be some small ones that we have not encountered.

Series 3. Some special interest has attached to the delimitations of the anorthosites north of Newcomb village, and it is

Plate 14



GEOLOGIC MAP OF NEWCOMB TOWNSHIP.

believed that we have the boundaries located with approximate correctness. We have been obliged to work with maps which are drawn on a very small scale, and are not at all accurate, and as the region is a heavily wooded one, and as the glacial drift in the valley of Cold river is heavy, outcrops have not been found with all desirable fulness. Typical anorthosite was met at no. 185 in a brook coming off the north side of Mt Santanoni. The brook was then traced down to Cold river and the river itself followed for two or three miles without meeting ledges or any rocks in place. The predominating float was however anorthosite. In 1898 one of us (J. F. Kemp) visited the Cheney ore bed about two miles west of the middle point of Lake Sanford, and anorthosite was found everywhere, except at the ore bed, where gabbro appears.

The anorthosites have been shown by the recent work of H. P. Cushing to extend a long distance into Franklin co. and to constitute a very large area in that section.

Series 4-5. No new observations of importance have been accumulated regarding these formations. There are no paleozoic rocks in the township. No new dikes have been met. The glacial drift is widespread. It embraces many boulders of anorthosite to the south along the highway beyond the Boreas river, but they then die out. They are abundant on Cold river to the town line but then die out. Potsdam sandstone appears in the drift in this region, but whence it came we can not positively state.

HAMILTON CO.

Long Lake

Only the eastern half of this town has been studied, as by arrangement with Prof. Smyth, the western half comes within his area.

Series 1. Nearly all the portion traversed by us has been found to be gneiss whose chief mineral is microperthitic orthoclase. Some light-colored varieties like 171, contain considerable quartz and but few dark silicates, those that are visible being chiefly brown hornblende. From this acidic extreme the rocks grade

down to those that are very rich in dark silicates. No. 173 is of this character, the dark minerals being hypersthene, green augite, and brown hornblende. Plagioclase is also present. The rocks are all variations, however on a single type and are the same as the gneisses described from Indian Lake and Newcomb.

The strike of the foliation varies a good deal. The commonest seems to be northeast, but northwest strikes have been recorded.

Series 2. The crystalline limestones have only been found where the Newcomb road crosses the town line. They presented no unusual features.

Series 3, 4 and 5 are entirely lacking.

Series 6. The glacial drift is abundantly developed and covers much of the town, specially near the shores of Long lake itself. Boulders enter largely into it. On Cold river, considerable anorthosite occurs in the drift, and rarely a Potsdam pebble may be seen. In the angle between Long lake and Cold river there is much clay, occurring about 3 to 4 feet above the water level. No glacial striae, distinct enough to measure, were observed.

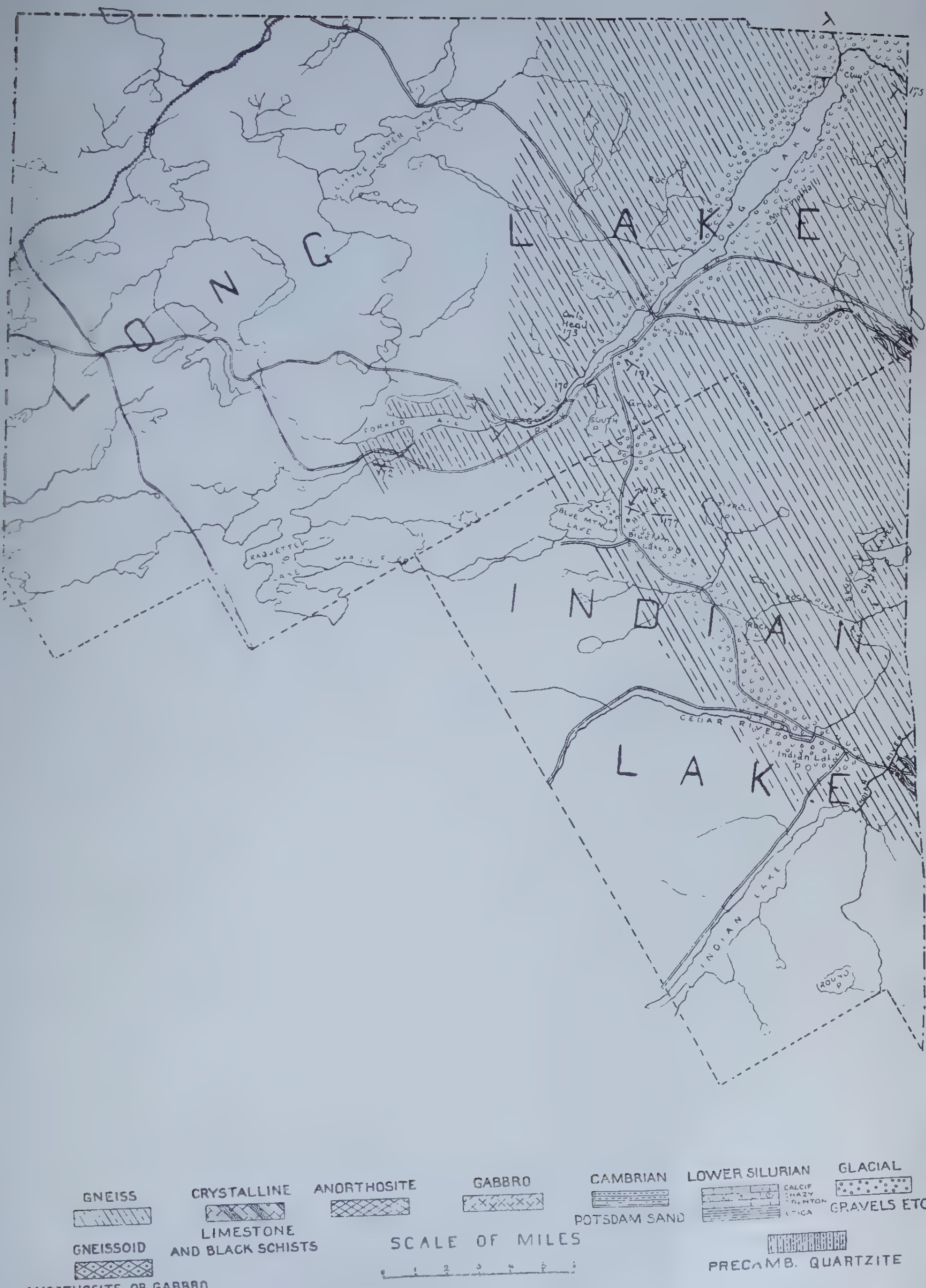
Indian Lake

Series 1. The portion of this township of Hamilton co. lying between the highway from North River to Longlake and the Essex co. line, has been investigated and has been found to be almost entirely gneiss. It is of the Whitehall type, and contains microperthitic orthoclase, some plagioclase, together with green augite, brown hornblende and occasionally hypersthene. Acidic varieties have quartz, and very basic ones are rich in the dark silicates. The prevailing strike is northwest with a tendency to approach an east and west direction.

Series 2. The crystalline limestones have been met where the highway crosses the line with Minerva, but they have not been elsewhere discovered, though the rather open and level character of the country would lead one to infer their more extended presence.

Series 3, 4 and 5 have been nowhere observed unless the gneiss referred to above belongs with Series 3.

Plate 15



GEOLOGICAL MAP OF LONG LAKE AND INDIAN LAKE TOWNSHIPS, HAMILTON CO.

Series 6, embracing the glacial drift is widespread. Gravel indeed covers so much of the town as to conceal a large part of the hard geology. Glacial scratches were observed on the west slope of Blue mountain and bore N 15 E. The topographic sheets will be needed in order to work out the further details of the township geology, but it is appreciated by us that some interesting problems in connection with the history of the drainage system, are presented.

INDEX

The superior figures tell the exact place on the page in ninths; e. g. 25^3 means page 25, beginning in the third ninth of the page, i. e. about one third of the way down.